# MEMOIRS

OF THE

LITERARY

AND

PHILOSOPHICAL SOCIETY

OF

MANCHESTER.

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## ERRATA.

Page 29 line 6, for "Troy" read Sardis.

Page 328 line 12, for "Tyrins" read Tiryns, also, pp. 331, 335, 336, 337, 339, 348, &c.

Page 571 line 12, for 52 read 25.

Page 579 line 13, for "HENRY WOOD" read JOHN WOOD.

## DIRECTIONS TO THE BINDER.

# MEMOIRS

OF THE

LITERARY AND PHILOSOPHICAL SOCIETY,

OF

MANCHESTER.

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## OBSERVATIONS

ON THE

## EFFECT OF SEVERE FROST

ON THE

## BLOSSOMS OF THE JARGONELLE PEAR

AT DIFFERENT PERIODS OF THEIR GROWTH,

AND ON THE

## COMMON METHODS

OF

PRESERVING

## WALL TREES FROM FROST.

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By JOHN MOORE, Esq., F.L.S.

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(Read February 24th, 1832.)

It appears to be the opinion of most gardeners that a mild winter is an exception to the general character of winters in this country, and this impression, no doubt, prevents many of those who obtain a livelihood by raising early fruits and vegetables for market, from making experiments which they apprehend would often end in disappointment and loss.

Fortunately however in the growth of the most useful of our fruits and vegetables the gardener has comparatively little to fear from the severities of winter; it is when sharp frosts succeed mild and open weather in the spring, that he suffers most; and as these not unfrequently occur in this part of England, it may be useful to record such observations as may instruct us to guard against them.

A person residing in the country and fondly attached to the pursuits of rural life will, no doubt, be apt to overrate the value of his remarks, but if they appear to have the remotest tendency to advance the physiology of vegetation, and especially of any of those more essential productions of our orchards or gardens which add so much to our support and comfort, there is no danger of their being uncourteously received by this society.

We are well aware how much the slow or rapid growth of vegetables depends upon temperature, and a proper degree of moisture in the air and ground; but we know comparatively little of the manner in which they appropriate to themselves the different kinds of nourishment which they receive from the air and the earth, decreed to

produce so wonderful a variety of hardy and delicate forms, of fragrant and splendid flowers, or of wholesome and delicious fruits.

The important investigations of vegetable structure and reproduction which are in progress by eminent botanists in this country and abroad, must undergo much familiar illustration before they can be generally useful to gardeners. I believe however it may be considered as clearly demonstrated that the access of a certain portion of common air is as necessary to the roots as to the leaves of plants, and therefore it is unreasonable to expect that trees will bear much fruit when they are surrounded by thickly matted grass or hard gravel walks.

The advantages of transplanting are founded upon the same theory. Cabbages, celery, and many other useful vegetables if suffered to remain in the seed beds, however much they may be thinned and separated from each other, seldom grow to a large size. By transplanting them we destroy the tendency of the roots downwards, and increase the number of those fibres which have an horizontal direction, thus giving them a more free access to the air as well as to the water which falls in showers, and enabling

them, by obtaining a greater supply of food, to support a proportionately greater luxuriance of foliage.

The two last weeks in April and the two first of May form a very interesting and anxious period to the gardener, as the buds of most of our useful fruit trees then begin to swell out and unfold themselves; and a severe frosty night, after rain or snow, may very much diminish the hope of a crop.

The following brief observations may perhaps assist us in determining the easiest and cheapest way to preserve some of our fruits and vegetables on such occasions.

The excellent markets which Manchester and the surrounding towns afford for choice vegetables, and especially for early potatoes, has induced our gardeners to pay great attention to raising them, and in doing this their first object is to throw their ground into a succession of beds all sloping to the south.

These are trenched two feet deep at the latter end of the year, and lie in ridges during the winter to get mellowed by the frost. About

the middle of February the early seed potatoes are taken from the store heap, and, being selected as nearly as possible of one size, are placed in single layers on the floor or shelves of some warm room, with a covering of damp saw dust about one inch in thickness. In a month or five weeks they will have put forth stiff sprouts of an inch or two in length with very delicate roots attached to them. A dry day is then selected to level the ground, and, small drills being made about six inches deep, they are filled to the extent of about one half their depth with rotten horse dung, the young roots of the potatoes being placed with great care upon its surface, and lightly covered up with soil extending an inch or two above the tops of the sprouts.

To protect the growth of these early potatoes it had always been the custom when frost was expected to cover them with mats or sheets spread closely upon the ground.

On the 28th of April, 1829, we had a severe frosty night, and on the following day the gardeners found that wherever the mats had been in contact with the soil the potatoe sprouts were frozen, and in many instances at nearly an inch below the surface.

One of my neighbours, being short of mats to cover the whole of his beds, laid old pea sticks upon them, scraping together any litter he could meet with to throw upon the pea sticks.

On the disappearance of the frost he was surprised to find that the potatoes so covered were much less injured than those covered by the mats, and since that time it has become the practice to form the covering into frames which can be elevated a short distance from the ground, that there may be air between the covering and the soil.

Some other observations which I made after this severe spring frost I cannot help thinking connect themselves physiologically with the safety which was afforded to the potatoes by their having an open space between the covering and the ground.

I had a Jargonelle pear tree much advanced at the time, and in a few days after the frost had ceased it became one complete sheet of blossom, affording to a cursory observer the promise of an abundant crop.

On a closer examination however most of the

buds which were open were found to be injured. After carefully watching the progress of many blossoms in the different stages of maturity I was led to the following conclusions, viz.:

1st. When a frost occurs in the spring after heavy dews or rain, the blossoms of pear trees which are fully opened, having their stamens and pistil both exposed, will, in almost every instance be destroyed.

2nd. Blossoms which are nearly opening, having the summit of the pistil in contact with the under side of the canopy formed by the petals above it, will have the pistil destroyed, whilst such of the anthers as do not touch the petals will be ininjured, but no fruit will succeed.

3rd. Blossoms wanting two or three day's growth to expand them, and neither the pistil nor the anthers touching the petals, but having an intervening space, will, if the succeeding weather prove favourable, almost invariably produce fruit.

The blossoms of pears are generally exposed to the air in an horizontal direction and are seldom pendulous like those of gooseberries and

currants; when however they point downwards I have sometimes known them to produce fruit after hard frosts, although fully opened at the time, plants like animals having in many cases a wonderful power of maintaining their proper temperature, when the temperature of the atmosphere which surrounds them is unfriendly.

Of apples, pears, and plums, the first blossoms which open, as they are almost invariably the largest, are also those which, if uninjured, produce the finest fruit, and it is therefore unreasonable to expect that the later and immature blossoms above referred to, although they may have escaped the spring frost, will yield very perfect fruit; hence it is that gardeners are the more interested in protecting wall trees in order to secure the first blossoms.

If in the case of the potatoes which I have stated, the sprouts were saved by the straw not touching the ground, and the seed vessels of the immature blossoms of the Jargonelle pear were also protected by having a plate of air between them and the unopened petals, we may, I apprehend, conclude that any covering of fruit trees or vegetables, in immediate contact with them, must be of little use against frost.

I believe the cheapest and simplest plan is to have sheets of close pressed or glazed linen attached to rollers working on pivots, which may be placed horizontally or perpendicularly as the case may require.

These may be easily rolled up in the morning and replaced in the evening, and being carefully preserved will last many years.

# AN ACCOUNT

OF SOME

# EXPERIMENTS

TO DETERMINE THE QUANTITY OF

# CARBONIC ACID IN THE ATMOSPHERE.

By WILLIAM HADFIELD.

(Read December 24th, 1830.)

The Gas denominated Carbonic Acid is found diffused through the Atmosphere, but in a very small quantity, in every part of the world. We find it at the surface of the earth, and in the most elevated situations. It is generated in certain caverns, mines, and deep covered wells; and being nearly fifty per cent heavier than common air, it does not make so great an effort to escape from those subterraneous abodes as it would otherwise do. The gas is formed in immense quantities in large towns from the combustion of fuel, and from the respiration of animals; but such is the still greater immensity of the atmosphere that the whole quantity of acid gas

is soon diffused and becomes almost insensible in the great mass of aerial fluid.

There are no experiments tending to shew whether the quantity of Carbonic acid gas in the atmosphere is upon the increase or decrease. From the above facts it is obvious that large additions are made to it every day; but some are of opinion that this gas is decomposed in the process of vegetation, in which the carbon enters the vegetable, and the oxygen is restored to the atmosphere. If this should be the case, which has not been satisfactorily proved, there may be a kind of equalization established between the animal generation and destruction of this gas. Mr. Dalton has made a calculation (see memoirs vol. 2nd. p. 41, second series) to shew that the quantity of acid gas at present found in the atmosphere may be no more than the natural produce of 6000 years, and that the supposed decomposition of it may not be necessary.

Under these circumstances it is evidently expedient that the quantity of acid gas now in the atmosphere, should be as accurately ascertained as is practicable.

Humboldt concluded from some experiments that the air contained about 1 per cent of carbonic acid gas. But Mr. Dalton found in his 'Enquiry into the properties of the several Gases constituting the Atmosphere.' (see Memoirs, vol. 1, new series) that the quantity was only $\frac{1}{1460}$ in volume, or $\frac{1}{1000}$ in weight; and since that time M. Saussure of Geneva has made abundance of experiments on the same subject, the results of which seem to shew that the quantity is somewhat less than that just assigned.

M. Saussure's method is to procure a large glass globe of known capacity, (one cubic foot or more) into which he passes a quantity of Barytic water, more than sufficient to neutralize the carbonic acid in that volume of air. By agitation, the carbonic acid is united to the barytes, forming an insoluble carbonate of the earth. The quantity of carbonate so formed being carefully ascertained, affords data for determining the quantity of carbonic acid.

Mr. Dalton considers a globe of one fifth part of the size sufficiently ample, and uses Lime water of a known strength instead of Barytic, taking care to have more than enough to engage the acid gas; after the agitation and absorption

the residue of lime water is poured out, and its reduced value is then ascertained, as it was before, by means of some test acid of a known strength, thus data are gained for the calculation of the carbonic acid engaged to the lime.

In my investigations of this subject I have adopted Mr. Dalton's mode, and from December 1828 to 1830 the experiments have been made in a glass bottle of a balloon shape, of the capacity of 471 cubic inches, fitted with a brass cap and stop cock for the purpose.

The experiments of the present year (1830) have been made in a larger bottle of the capacity of 498 cubic inches. The method of filling the latter bottle with air was a little different from that of the former, for instead of filling the bottle with rain water, as was the case with the first bottle, to get the air in, the end of a bellows pipe was introduced into the latter and the air blown in.

December 20th. 1828.

EXPERIMENT 1.

The balloon shaped bottle was filled with air from Cornbrook, and 2oz. measures of lime wa-

ter put in. 2 oz. measures of this lime water before going into the bottle took 10.8 gr. measures of test sulphuric acid, equal 17 gr. acid in 100 gr. measures. The lime water was in the bottle 10 days, and well agitated 8 or 10 times each day, and then poured into a glass jar, and allowed to stand until all the carbonate of lime had fallen to the bottom, then carefully neutralized, taking 9 gr. measures of the test acid to neutralize the 2 oz. measures of lime water; being 1.8 less than before it was put in.

This gives $\frac{1}{869}$ by weight and $\frac{1}{1327}$ by volume.

February 9th, 1829.

EXPERIMENT 2.

Filled the bottle again with air at Cornbrook, and put 1 oz. of lime water in, this air was in the bottle 4 days, and agitated as before, and when the lime water was taken out it took 3.25 gr. measures to neutralize it; 5 oz. of the above lime water took 26.5 gr. measures of the test acid to neutralize it.

This experiment gives $\frac{1}{763}$ by weight and $\frac{1}{1165}$ by volume.

March 14th, 1829.

### EXPERIMENT 3.

Filled the bottle again with air at Cornbrook, and put in 1 oz. measure of lime water; 5 oz. of which took 26.5 gr. measures of test acid to neutralize it, this air was only in 2 days, and agitated as before, when the lime water was taken out it took 3.5 gr. measures of test acid to neutralize it.

This gives $\frac{1}{869}$ by weight and $\frac{1}{1327}$ by volume.

June 27th, 1829.

### EXPERIMENT 4.

Filled the bottle again with air at Cornbrook, and put 4.80 gr. measures of lime water in; 5 oz. measures of which took 27 gr. measures of test acid to neutralize it, this was in 3 days and frequently agitated; when taken out again 3.8 gr. measures of test acid neutralized it.

This equals $\frac{1}{975}$ by weight and $\frac{1}{1488}$ by volume.

August 4th, 1829

EXPERIMENT 5.

Filled the bottle again with air from a Field adjoining the road between Manchester and Stretford, near to Old Trafford, and put in 1 oz. measure of lime water; 5 oz. of which neutralized 27 gr. measures of test acid, when taken out again in 7 days, took 3.35 gr. measures of test acid to neutralize it.

This equals $\frac{1}{770}$ by weight and $\frac{1}{1176}$ by volume.

July 28th, 1830.

EXPERIMENT 6.

This time the large bottle was filled with air at Cornbrook, and 500 gr. measures of lime water put in, and 500 of this lime water before going in took 5.5 gr. measures of test acid to neutralize it, and when it had been in 2 days, having been well agitated, it took 3.8 gr. measures of test acid to neutralize it.

This equals $\frac{1}{985}$ by weight and $\frac{1}{1510}$ by volume.

July 31st, 1830.

EXPERIMENT 7.

Filled the above bottle again with air from the field, as in experiment 5th, and put 1000 gr. measures of lime water in; 1000 gr. measures of this lime water before going in, took 11 gr. measures of test acid to neutralize it, and when taken out again after being in 6 days, and well agitated, it took 8.3 gr. measures of test acid to neutralize it.

This equals $\frac{1}{620}$ by weight and $\frac{1}{947}$ by volume.

August 17th, 1830.

EXPERIMENT 8.

Filled the bottle again with air taken at Cornbrook, 500 gr. measures of lime water were put in; 500 gr. measures of this lime water before going into the bottle took 4.7 gr. measures of test acid to neutralize it, and after being in the bottle 8 days it took 2.2 gr. measures of test acid to neutralize it.

This equals $\frac{1}{670}$ by weight and $\frac{1}{1023}$ by volume.

September 1st, 1830.

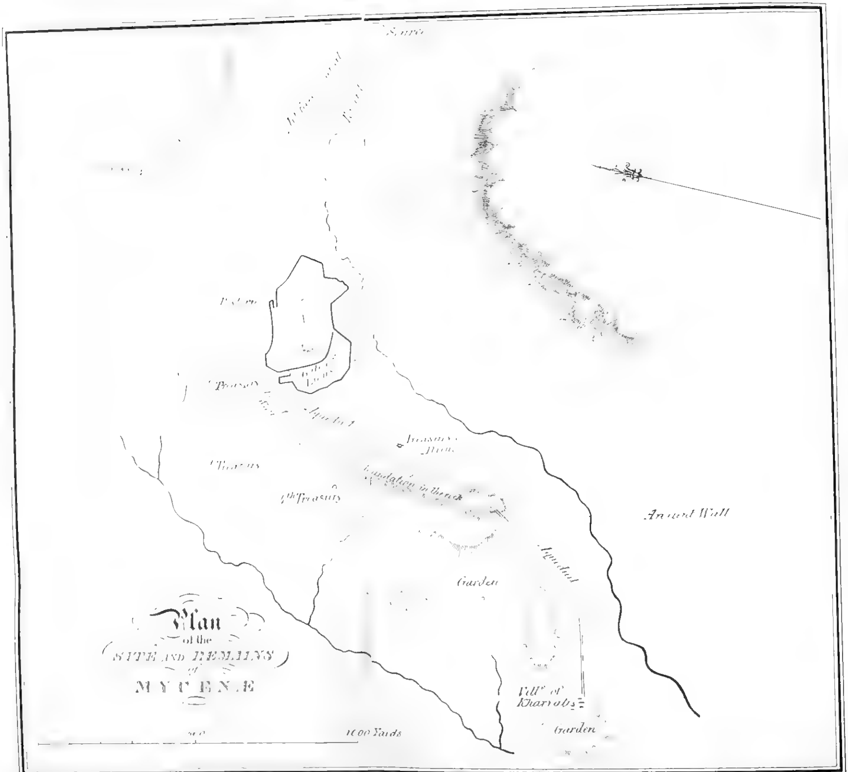
EXPERIMENT 9.

Filled the bottle again with air from the field as before and 2550 gr. measures of lime water; 2550 gr. measures of this lime water took 22 gr. measures of test acid to neutralize it, and having been well agitated, it took 20 gr. measures of test acid to neutralize it, and after being in 4 days, and having been well agitated, it took 20 gr. measures of test acid to neutralize it.

This equals $\frac{1}{775}$ by weight and $\frac{1}{1182}$ by volume.

RESULTS.

| 1828. | Experimt. | 1 Grain Carbonic Acid in | 1 Cubic Inch Carbonic Acid in |
|---|---|---|---|
| December 20th.................. | 1 | 869 air | 1327 air |
| 1829. | | | |
| February 9th.................... | 2 | 763 " | 1165 " |
| March 14th...................... | 3 | 869 " | 1327 " |
| June 27th....................... | 4 | 975 " | 1488 " |
| August 4th...................... | 5 | 770 " | 1176 " |
| 1830. | | | |
| July 28th....................... | 6 | 985 " | 1510 " |
| —— 31st......................... | 7 | 620 " | 947 " |
| August 17th..................... | 8 | 670 " | 1023 " |
| September 1st............. ..... | 9 | 775 " | 1182 " |
| Means.................... | | 811 | 1239 |




T. Physick, Lith.

# ON THE SEPULCHRAL MONUMENTS OF SARDIS AND MYCENÆ.

By WILLIAM RATHBONE GREG, Esq.

(Read December 13th, 1833.)

"Years roll away——oblivion claims
Her empire o'er heroic names;
And hands profane disturb the clay
That once was fired by glory's ray,
And avarice from their secret gloom
Drags e'en the treasures of the tomb."

ALARIC IN ITALY:—MRS. HEMANS.

To look back upon the history, and to trace the monuments of remote ages, is one of the most invaluable privileges of literary leisure. And no one can indulge, even for a few moments, in such an occupation, without feeling forcibly the truth of Dr. Johnson's remark, as to the elevating influence of such studies on the mind. The occasional indulgence of them, in addition to the genuine pleasure it bestows, tends almost insensibly to give us juster notions of the relative value of what is present and immediately

around us;—and by stripping the common interests of life of that inordinate importance which, in the absence of better thoughts and occupations, they invariably assume, confers upon us an obligation of surpassing weight.

To look back from the gloom and the feverish activity of our native town, upon the ruins of Mycenæ and the plain of Sardis, is assuredly a grateful task; and it can not be otherwise than beneficial to have our thoughts occasionally recalled from the weary and absorbing interests of the passing hour, to meditate on the dim and beautiful twilight of antiquity, and become chastened and elevated, though it be but for a moment, by the contemplation of those monuments of past time, which have survived the lightening and the hurricane,—the army and earthquake,—and the lapse of nearly thirty centuries.

It is not uninteresting to observe how generally the monuments, erected in honour of the dead, have outlived those reared for the use or the luxuries of the living. Thus, in the East, we constantly meet with extensive cemeteries, standing alone in a deserted region, where the cities which peopled them have been entire-

ly swept away, and where no human habitation can be found for many leagues.—On the plain of Troy, the Tumuli are the only remaining monuments of a time celebrated beyond all others in the history of mankind;—the Pyramids of Egypt have long survived the cities of the monarch who erected them;—at Mycenæ, the *Tombs* of the Atridæ may be seen in their original integrity, though their *Palaces* have left no vestige behind them, and their massive Citadel is fast crumbling into ruins;—and of the renowned and magnificent Sardis, the only uninjuredrelic which has reached our timesisthe sepulchre of the sovereign, who first raised it into splendour.

To whatever part of the world we turn our attention, we find Barrows or Tumuli in great abundance, and differing from each other but little, either in construction or in form.—They are generally conical hillocks, of larger or smaller dimensions, constructed sometimes of earth, sometimes of stone,—in some cases solid,—in others containing a vaulted chamber.—In our own country they are found in Cornwall, and more especially in Scotland and the Orkneys, where they are known under the name of *Cairns*: Dr. Clarke relates having met with them abun-

dantly in the *Steppes*, or vast plains in the South of Russia;—and I found considerable numbers in Roumelia, both north and south of the Balkan, and also in Servia and Bulgaria.—Jefferson (in his "Notes on the State of Virginia,") describes many of them in different parts of the New World;—in Africa they are said to be not unfrequent; and in Greece and Asia Minor they are seen in unusual quantities, and of extraordinary dimensions.—Having had the good fortune to visit several of the more celebrated of these Barrows, it may not perhaps be wholly uninteresting to the Society to hear a short description of the two which most deserve our attention,—viz., those at Sardis and Mycenæ.

To commence with the latter.—The plain of Argos, in the N.E. of the Morea, is an extensive semicircle of flat, and for the most part, marshy land, situated at the head of the Gulph of Nauplia, and apparently reclaimed from the sea at no very remote period, as indeed mythological history plainly indicates.—It is inclosed by a vast amphitheatre of hills, among which is situated *Mycenæ*, the city of Atreus and Agamemnon, said to have been founded by Perseus, about 1300 B.C.—Its remains are very accurately described by Pausanias, who flourished A.D. 180; though Strabo declares that in his time (B.C. 10)

Walls of Mycenæ

no vestige of it existed, and that its site was entirely unknown.—It is not however easily to be found even by those acquainted with its general position;—for though myself and my companions were furnished with the best maps, and travelled Pausanias in hand, it was not till the second day's search, that we were at length rewarded by stumbling upon the Citadel, among the low hills near the village of *Charvati.*

The Acropolis of Mycenæ is a rocky hill entirely surrounded by walls, which in many parts are still tolerably perfect, and, except at intervals, are of the oldest style of Cyclopian architecture. Of the Pelasgians or Cyclopes, to whom all the most solid and stupendous structures of ancient Greece and Italy are, by common fame, attributed, we know almost nothing;—nor has the profound and patient genius of Niebuhr succeeded in throwing any material light on the origin, history or achievements of this singular and powerful people.—Their national existence would seem to have been almost terminated before the commencement of the historic era;—and many of the most ancient and remarkable cities in Greece Proper and Magna Grecia appear to have been founded by them, either while existing as an independent people, or after their subjugation by other Greek tribes.

It is not my intention to enter here into a description of the massive monuments which bear the Pelasgic or Cyclopian name,—but it may be important to remark, that they consist of three distinct styles, which I should conceive to be referable to widely different periods of time.—The first, which appears to be the most ancient, consists of walls formed of immense blocks of stone, roughly, if at all, hewn, generally of a square or oblong shape, put together with little care, and having the interstices filled up with stones of smaller dimensions. To this class may be referred the outer walls of *Tiryns*, the Pelasgic wall round the citadel of *Athens*, and a large part of the acropolis of *Mycenæ*.—The second style includes those buildings which are constructed of enormous blocks of every imaginable shape, but most commonly pentagons, and irregular rhomboids, and fitted together with the most scrupulous and beautiful exactitude. The galleries of *Tiryns*, some fragments which surround the hill of *Argos*, and others near *Arpino*, in the Southern Apenines, are the only specimens of this class I have seen. —The third and most modern division of Cylopian architecture, is of a far more finished, and somewhat less massive character;—and the Tomb of Agamemnon at Mycenæ, which forms

the subject of this paper, is, as far as I am aware, the only instance of it extant.

The mystery, which hangs over the origin of these massive structures, their singular appearance, and remote antiquity, all conspire to render them most fascinating objects of research. But at Mycenæ our interest was more peculiarly awakened by the celebrated *Gate of Lions*, the entrance to the Acropolis, and the one through which Agamemnon led his army to the siege of Troy.—It is formed of two upright slabs of stone, 17 feet high, and supporting an entablature of similar proportions, viz., 15 feet long, 6½ feet thick, and 4 feet deep, hewn out of a single block. Resting upon this entablature, is a triangular slab, 10 feet high, containing in relief the figures of two Lions, standing on their hind legs on each side of a pillar, the summit of which has been broken off.—On the whole, it is a most magnificent gateway; and on gazing on it, we are at a loss to conceive how, in those remote times, men could have acquired sufficient command of mechanical agents, to raise and place such enormous masses.

About fifty yards from the Gate, and outside the walls of the Acropolis, stands the immense

mound, which forms the more immediate subject of these remarks.—It is a large, round, conical hill, partly natural, partly artificial,—and considerably lower on one side than on the other. On the side nearest to the Citadel an excavation has been made, which succeeded in laying bare the entrance or doorway, a structure of even more gigantic dimensions than the Gate of Lions. On entering this we come into a large vaulted chamber, inclining to the conical form, 50 feet across at the base, and about 45 feet high. Adjoining this is an interior chamber of square form, and smaller dimensions.

The chief peculiarity in this beautiful monument struck me as being the extreme neatness and regularity of the masonry. It contains forty courses of hewn stone, all admirably fitted together, but without cement;—and it is I should think, quite as perfect a specimen of workmanship as could be produced at the present day. The annexed drawing will give a more accurate notion of it than any description.

Great doubt exists among the learned, as to *what* this monument really was,—some calling it the Tomb of Agamemnon, and others the Treasury of Atreus.—Dodwell and Dr. Clarke

*Entrance to the Treasury of Atreus*

T. Physick Lith

hold the former opinion, while Col. Leake and the generality of travellers are strenuous advocates of the latter.—The only authorities, on which we have to rely, are the description of Pausanias, and the plays of Sophocles and Euripides.—From the former, it appears more than probable that the Treasury of Atreus was *within* the Citadel;—and indeed we can scarcely conceive that any Monarch who possessed a fortress as strong as that of Mycenæ, would deposit his treasures any where but within its walls. Now the Monument in question is *outside* the fortifications, and therefore can scarcely be the treasury of Atreus.—Again Pausanias places the Treasury near the Spring Persea which in no way corresponds to the position of the Tumulus we are examining, as may be seen by the annexed Plans;—for the only two rivulets to be found at Mycenæ, rise one or two hundred yards distant.—Now we gather from different passages in the Electra of Euripides, as well as from that of Sophocles, that the Tomb of Agamemnon *was* without the walls, (although Pausanias seems to indicate the contrary,) for Sophocles describes Orestes as visiting his father's sepulchre, before he reached the Gate of the Citadel;—and in Euripides, when Orestes relates to Pylades his nocturnal visit to the Tomb, it is

expressly stated that he repaired thither without entering the walls.—Now the Tumulus in question *being* without the walls, and being also by far the largest to be found at Mycenæ, may fairly be conceived to belong to so celebrated a Monarch;—and to make assurance doubly sure, we learn from Sophocles that the Sepulchre (Ταφος) of Agamemnon *was* a Mound or Barrow (Κολωνη).

I have unfortunately neither the classic lore, nor the habits of antiquarian research, which could alone entitle me to form an independent opinion on this controverted point. Certainly from considerations abovementioned, I incline to Dr. Clarke's view of the subject. But the decision of the question is now of little moment;—for whether it be the Sepulcre of the "King of Men," (αναξ ανδρων), or the Treasury of his father, the bones of the one and the treasures of the other have alike disappeared;—and the Grecian shepherds, with their flocks and herds, are now the only inhabitants of this magnificent abode of grandeur and of gloom.

Passing over two Barrows of unrivalled interest, that of the Athenians on the Plain of Marathon, and that of Achilles on the Plain of

Troy,—both of which have attracted so much attention from all travellers that it would be impossible for me to add any thing to their descriptions;—let us proceed to cast a short glance at the Tomb of Alyattes, which is situated in the Plain of Troy.

Sardis is about two days journey to the N.E. of Ephesus, from which place I set out to visit it. On the second day we passed Mount Tmolus, an extensive range which runs through Asia Minor, parallel to the two seas.—These hills are extremely wide at their summit, and are covered with a rich, soft grass, and ornamented by trees not inferior to the finest to be met with in our English parks.—As we descended on the northern side, the Pactolus with its golden sands, now an insignificant streamlet, murmured gently by our path, sparkling with the dazzling beams of an Asiatic sun, from which even the rich foliage which hung over was unable entirely to protect it.—A sudden turn at length brought us full upon the narrow glen which contains the Temple of Sardis, the only existing remnant, except the Acropolis, of the ancient city of Crœsus.—The Temple is a most beautiful specimen of the Ionic order;—and though two only of the columns are now erect,

yet the others are lying around so little injured, that they might without much difficulty be replaced in their original position.—It was curious to see our Turkish attendant sauntering amid the ruined fragments, and endeavouring with all the honest politeness of his nation, to sympathize with us in our admiration of their beauties;—though evidently extremely at a loss to conceive, what should have induced us to come so far, merely to gaze upon the fallen columns, and scattered friezes of an ancient Temple.

But the description of Sardis, however beautiful or striking it may have been, is not our present object.—About a mile beyond the Temple, the glen opens into a wide plain, in which the cavalry of Lydia were defeated by the elephants of Cyrus.—It is a truly oriental scene;—the plain is of vast extent and is surrounded by hills on all sides;—at one extremity stand the Lake of Gyges, and the renowned Tumulus of Alyattes.—The sun was setting, as we caught the first glimpse of this lovely landscape;—its lurid rays shone over the still surface of the lake, the habitation of innumerable swans;—the black canvas tents of the Turcomans (a wandering Asiatic horde) were scattered in

profusion over the plain;—camels and goats were feeding tranquilly around them;—and the wild figures and uncouth dresses of the Shepherds might be seen hurrying to and fro, to call the cattle to their nightly quarters.

The Gygian Lake is a wide piece of water, by the banks of which, on the side nearest to the town, are great numbers of barrows or mounds of earth, and among them the Sepulchre of Alyattes stands pre-eminent. Herodotus, I. xciii, who probably lived about 450 B.C., speaks of it as being, next to the works of the Egyptians and Babylonians, the most stupendous monument existing.—It was constructed, he says, upon a foundation of stone, and afterwards completed with earth. It was erected by three classes of the inhabitants of Sardis, viz., the merchants, the artisans, and the public women. At the summit of it were fixed five *termini*, or small pillars with inscriptions, declaring the proportion of work executed by each class of the artificers. Of these there is now no vestage.—In the time of Herodotus this monument was somewhat more than three quarters of a mile in circumference at the base, but at present it is considerably less. Unfortunately he does not mention its height, nor had I, when there,

the means of measuring it, but it could not fall far short of two hundred feet. Several attempts have been made to effect an entrance into the monument, under the idea that treasures would be found there; but hitherto little more has been done than to scratch the surface; and the interior construction of one of the most ancient sepulchres in the world, (B. C., 560) is still a secret.

Though there is less of mystery, there is scarcely less of interest, connected with this enormous barrow, than with the one at Mycenæ.—We know beyond all doubt, that it is the monument of Alyattes, the father of Crœsus, and the king of Lydia. We know, that it was erected by order of the wealthiest monarch of Asia, that it was described by Herodotus, and that it must have been visited by Solon;—and there is surely enough of magic in these associations, to awaken our warmest sympathies for this mighty relic of a people, whose fertile empire is now a desert, and whose once formidable name is almost lost in the remoteness of past time.

CONSULT:—

Pausanias Homer, Sophocles *Electra*, Euripides *Electra*,
Gell's Topography of the Morea,
Leake's Ditto Ditto
Leake's Journal in Asia Minor.
Dodwell's Tour in Greece,
Herodotus—*Clio*,
Dr, Clarke's Travels,
Dr, Chandler's Travels, page 363,
Cockerell,

# ON THE PROBABLE ORIGIN OF MODERN CORPORATIONS FROM THE MUNICIPIA OF THE ROMANS, AND THEIR SUBSEQUENT INTERNAL CHANGES.

BY THE REV. JOHN KENRICK, M.A.

(Read, October 16th., 1835.)

THE condition of Europe in the middle ages is a subject which is far from being exhausted, notwithstanding the learning that has been employed in searching into its antiquities. Everything connected with the tenure of land has indeed been collected and commented upon by our antiquaries and lawyers, because this tenure was the foundation of aristocracy through all its gradations; but the institutions by which the people were raised from personal or political slavery, so as to influence the administration of government in nearly all the countries of Eu-

rope, in some to controul or share it, have attracted, comparatively, little attention. Yet, if we can withdraw ourselves from the illusion created by baronial pomp and the romantic splendour of chivalry, and estimate the share which each order has borne in the improvement of social institutions, we shall find the pre-eminence to belong to the *third estate*, of which the inhabitants of cities form the most important element. Collected in cities, men enlighten each other by the ready communication of ideas; they combine their forces for a common object, and enthusiasm kindled by sympathy prompts them to undertakings for the extension of their liberties, which would have appeared too hazardous, if coldly calculated in solitude.

From the end of the eleventh century downwards, the influence of cities in promoting the increase of wealth, liberty and knowledge, is sufficiently conspicuous, and historians have generally found it more interesting to trace this influence into the great political changes which resulted from it, than to enquire how the cities had become what they then were. It is indeed an obscure and unpromising inquiry: from the time of Charlemagne to that of the crusades is the darkest period of the middle ages, and little

information was to be expected from the chronicles of those times, respecting the silent growth of institutions which had not yet begun to exert any visible influence.

The striking resemblance between the municipal corporations of the Romans in the later ages of the empire, and those of the cities which in the the twelfth century emancipated themselves from the feudal yoke, could not but excite a suspicion that the one were derived from the other. This suspicion, however, was almost immediately repelled by the conviction which long prevailed, that almost every trace of Roman laws and manners had been obliterated by the invasion of the barbarians. More accurate research has shewn the fallacy of this opinion: a close resemblance to the feudal tenure of land has been perceived in the tenure of the Lætic lands under the emperors; Savigny* has described the condition of the *Coloni* in such a way, as to show that the state of villenage preceded the irruption of the barbarians. No one now believes that the discovery of a copy of the Pandects at Amelfi in 1137, was the first thing which made the nations of the west acquainted with the labours of the imperial lawgiver. Even

* Philolog. Museum, v. 2, p. 116, seq.

in the English common law, which it was long the pride of our jurists to consider as wholly independent of the civil law, indisputable traces of its influence have been pointed out.* The question respecting the connexion between the Roman municipia and our modern corporations, has assumed a new appearance, since these facts have been established, and instead of saying that the institutions of the cities of the middle ages cannot have originated from the Romans, because all knowledge of their laws and institutions had perished, we are entitled to say that the preservation of so many doctrines and forms of Roman law in the barbarian codes renders it probable, that the administration of justice and maintenance of order in the cities may have been carried on by forms and principles also derived from the practice of the Romans.

If it could be shown, that a chain of tradition connects the Roman municipal governments with modern corporations, we should have another exemplification of a principle which, I believe, pervades all history — that even those periods in which the greatest changes have taken place, will not be found to be separated from preceding times by any such gulph as is

* Spence's Inquiry, p. 533, seq.

commonly supposed, and that even revolutions leave most things unchanged. The historian, as well as the natural philosopher, must suppose at some time or other an *absolute beginning*, a *creation out of nothing*, but what each can trace, and what forms the science of each is a series of changes, in which the older condition of things always furnishes the material for the newer.

The identity of the Roman with the modern municipal institutions was little more than a presumption and a conjecture, until the appearance of the researches of Savigny, the eloquent juristical professor of Berlin. His name must be familiar to every reader of Niebuhr's history, in which it occurs repeatedly, and never without some expression of affection and veneration. These eminent men appear to have lived in the most unrestrained communication of their thoughts, and as Savigny suggested to Niebuhr many explanations of his difficulties, he derived from him the hint, which led him to trace the continuance of the municipal institutions of the empire among the barbarians. This subject occupies the principal part of the first volume of his *Geschichte des Römischen Recht im Mittelalter*, (History of the Roman Law in the Middle

Ages) which has been translated into English by Mr. Cathcart of Edinburgh; and it is the design of this paper to give some account of the evidence which he has produced in support of his opinions, and then to pursue the history of the municipal system on the continent, on which much light has lately been thrown by another German writer, Hüllmann, in his *Städtewesen des Mittelalters,* (Condition of the Cities in the Middle Ages.)

To enable us to judge how far Savigny has succeeded in establishing the descent of our modern corporations from Roman *municipia,* we must revert to the time immediately preceding the overthrow of the western empire. In Italy itself, after the Roman dominion had extended over the whole of it, the *municipia* and *coloniæ* possessed the right of self-government, as far as their internal affairs were concerned, choosing their magistrates and making laws for their own regulation. The constitution was at first popular, but became by degrees more oligarchical, and the *curia* or council, which had been only a branch of the executive, at length obtained the whole power for itself; as at Rome, the senate, from the time of Tiberius, made the elections and transacted the other business,

which had formerly been brought before the assembly of the people. Even in the time of Augustus, as we find from Suetonius (Aug. c. 46) when the cities of Italy were allowed to send written suffrages to the elections at Rome, this privilege was confined to the decurions or members of the municipal council; and as every popular institution was an object of alarm to the emperors, it was natural that they should limit power more and more to this oligarchical body. The distinction which Gellius makes between *municipia* and *coloniæ*, of which the former retained their own laws, the latter obeyed those of the Romans, appears to apply to countries in which the Romans found flourishing and well policed cities at the time of their conquest, not to those of western Europe, in which few cities existed before that time, and those which did exist had probably no organized form of independent government, with the very rare exception of those which, like Marseilles, derived their origin from a civilized people. The members of the council, which was named *ordo* or *curio*, usually one hundred in number, were originally selected from among the principal possessors of land, and in the case of the Gallic and probably other cities, the old native aristrocracy were largely incorporated with it.

Twenty-five *jugera* of land was the qualification which a plebian must possess in order to be elected to this office, which descended hereditarily and could at first be held only by those who were not engaged in commerce. The business of the *curia* was the management of the internal affairs of the city. The Italian *municipia* had magistrates called *Duumviri* (generally two, as the name implies, sometimes four) annually chosen from and by the *curia*, who had jurisdiction in civil causes of small amount, and were charged with the maintenance of order; but in the provincial cities this magistracy did not exist, except where a city possessed the *Jus Italicum* according to Savigny. Whether this was the ground of the distinction or not, it is certain that few cities of western Europe, except those of Spain, had a *Duumvir*. His place was supplied partly by the *Principalis*, the oldest decurion on the roll, who presided over the *curia*, but without jurisdiction, partly by the Roman governor, who exercised an appellate jurisdiction over the decisions of the *Duumviri*, and in the first instance, in person or by his delegates, in cities where no *Duumvir* existed. The *Defensor*, who had been originally appointed to defend the plebeian citizens against the tyranny of the *curia*,* gradually acquired the

* Savigny, p. 69, of Cathcart's translation.

rights of magistracy, and was invested with them generally by Justinian in cities which had no *Duumviri*.

Originally then the *Curia* was not a court of justice, but it exercised some functions out of which jurisdiction naturally grew. That of the Roman magistrates was of two kinds *contentiosa*, the decision of suits; and *voluntaria*, the performance and attestation of those solemn legal acts, to the validity of which the publicity of a court was necessary. The more important of these, all that related to manumission, adoption and emancipation, appears not to have belonged to the provincial city magistrates, nor to the *Defensor*, who came at length into their place; but donations beyond a certain amount, which by the *Lex Cincia* had not been valid, unless accompanied by an immediate transfer, were allowed under the Emperors to be validated by a protocol made in court and in the presence of a certain number of the *Curiales*, *Principales* or *Decurions;* for these names appear in later times to have been almost promiscuously used. A constitution of Honorius* fixes the number at three, besides the magistrate and the *Exceptor*. To the old and tedious forms of the solemn

*Savigny, p. 94.

testaments succeeded under the emperors a more compendious method of making out a protocol of the will in court, previously to the testator's death, the magistrate and *Curia* acting the part of witnesses, besides which in the case of a solemn testament, not published till after the testator's death, the *Curia* was the place of publication, and a protocol of the whole transaction was drawn up under its sanction. Probably many other acts of sale, barter, &c., to which the authority of the *Curia* was not required, were voluntarily performed there, to obtain the double advantage of publicity and a permanent record. The participation of the *Curia* in the contentious jurisdiction is in itself not doubtful, although the manner in which it was acquired is not distinctly related. It is thus explained with great probability by Savigny, (p. 84, seq.) Originally a Roman magistrate decided only the law of a case brought before him, prescribed the mode of proceeding and pronounced a conditional judgment, remitting the investigation of the facts to a *judex*, who having ascertained them, pronounced an absolute decree, according to the instructions of the magistrate. In the imperial times the right of the magistrate to employ a *judex* was very much restricted, and he was required to

pronounce the law and inquire into the facts; but at the same time a custom grew up which relieved the magistrate from part of his enormous labour. The *prætor* under the republic, when not a jurist, had been attended by assessors and advisers, and when the emperors absorbed all jurisdiction in their own tribunals they were compelled to appoint a permanent body of the same kind. The governors of the provinces imitated their master, and availed themselves of the aid of assessors; and though it is not expressly said that the city magistrate did the same, and made the members of the *curia*, already associated with him in the voluntary jurisdiction, his assessors also in the contentious, the change is so natural in itself, and serves so well to explain the subsequent state of things, that we cannot hesitate to admit its reality. But be this as it may, the existence of the *Curia* in the Roman cities, as the body before which transactions must be validated, down to the time of the barbarian invasion, admits of no doubt, and in the laws of the Ostrogoths and the Franks after that event, nearly the same forms and names are retained.* When the supreme authority passed from the emperors to the new sovereigns of the barbarian kingdoms,

Savigny, p. 97.

the delegated powers of the civil governor, the *Rector* or *Judex*, and of the military commander, the *Dux* or *Comes*, were transferred, originally without separation, to the duke or count appointed by the king. But this substitution of their own system for that of the Roman empire was by no means carried so far, as to banish the law or even the forms which had been previously established, where any considerable Roman population still remained. Not only was it the privilege of every one of German extraction to be judged according to his hereditary law, though different from that of the kingdom in which he was settled, but those of Roman descent were entitled to an adjudication according to the forms and principles of Roman law. Hence the distinction of *personal law.*—This they could obtain only by the ancient constitution of the *Curia* being preserved, the barbarians themselves being too ignorant to administer Roman law, although judicial proceedings might be carried on under their presidency. The privilege of being so judged the Roman population were not likely ever to abandon, and the barbarians, who before they left their native country had scorned the confinement of walls, appear to have contented themselves with the occupation of the land, and to have left the old inhabitants of

the cities without much disturbance to the enjoyment of their ancient customs. The progress of amalgamation between the new settlers and the old possessors, out of which arose the blended population of the cities at the commencement of their new activity and prosperity in the eleventh and twelfth centuries, cannot of course be distinctly traced; but admitting that the Roman law had ceased before this time to be administered, as their personal law, to any body of people in the barbarian kingdoms, it must still be regarded as highly probable, that the Roman institutions would be preserved, if not with all the fullness and detail of the imperial times, yet in their most important and characteristic circumstances. The growth of feudalism between the ninth and the eleventh centuries, tended more and more to obliterate the remains of the Roman law; but this growth was not equally rapid in all parts of Europe, nor even of the same country: in the north of France it completely predominated, and the Roman institutions disappeared. Accordingly the communities which were so generally established there from the time of Louis le Gros appear as innovations. In the south of France on the contrary the Roman population appears, both from the form of the new language, and from the preser-

vation of the civil law, to have been strongly preponderant, and here and in the north of Italy we must look for the marks of such a protracted existence of the old municipal institutions, as may connect them with the new communities. We find Roman and Salic *Scabini*, *echevins*, mentioned together in a placitum of the year 844 at Cahors, and Gothic, Roman and Salic Scabini and Rachinburgers, in 918, at Ausonne. At Narbonne in 933 there were Gothic, Roman and Salic Judices, and in 968 at a Placitum of William, Count of Provence, the Roman and Salic extraction of the judges is mentioned, although they are all called *vassi dominici*.—(Savigny p. 305.)

Savigny endeavours to prove that the *Rachinburgers*, *Racinburgi*, who have been commonly supposed to be an order of judges, and nearly the same with the *Scabini*, were no other than the decurions of the Roman *municipia* and were also the same as the *Boni homines*. The name he derives, not as has been generally done from *racha*, 'a process,' or *recht*, 'law,' but from *rek*, 'great, noble, excellent,' a name certainly not unsuited to describe an aristocratic body like the decurions, could it be proved that the Rachinburgers were the same class. But the proof

of this is hardly even attempted by Savigny. He observes indeed (p. 202) that the name is used where there is no judicial duty to perform. But if the duty in connection with which the Rachinburger is mentioned be not always strictly judicial, it is always something which originates or terminates in judicial proceedings; as enforcing obedience to a decision, compurgation or the attestation of a deed. Now if the Rachinburgers had been 'the rich men' of the community, would their name have been found thus exclusively connected with the courts of law? The evidence upon which Savigny would identify the *boni homines* of the Frankish and Lombardic documents with the decurions is equally slight and unsatisfactory, (p. 425, seq). If the old decurions still existed when the denomination of *guten leute, boni homines,* came into use, no doubt it would be applied to them, as forming an aristocracy in the community; but that the decurions and they alone are to be understood by *boni homines* is not rendered in the least degree probable by the arguments of Savigny, which only prove that the decurions were *boni homines.* The spirit of the German institutions was most directly opposed to any aristocratic monopoly of judicial functions;—every freeman was with them a judge, and they

only slowly yielded to the necessity which the more complicated relations of their new state of society produced, for the appointment of permanent judges, and the delegation of the power of decision to a jury. Every freeman, that is originally every possessor of land, was therefore also an *Ariman* (*Ehrenmann*) or *bonus homo.** But this state of things could not be permanent; among the freemen themselves distinctions of property and consequently of station and supposed fitness for office gradually arose, and the name, which had included all, was limited in its application to those whom the prejudice of mankind in favour of the possessors of wealth regarded as exclusively 'respectable people.' Such has been in other languages the process by which names descriptive of moral quality have been appropriated to a certain class in society. Such a class would form itself especially in the cities, and by the hereditary transmission of property would tend to hereditary aristocracy. Freedom was no doubt essential to the character of a *bonus homo,* and the property, which was not less so, was commonly property in land; but, after the rise of the cities to opulence, it is clear that the amount rather than the source of wealth was the circumstances on which the ap-

* Savigny conjectures with some probability that *Gothi, Goti,* is the same word as *good.*

pellation was founded. The language of laws and documents, which Savigny brings forward (p. 425) from the Middle Ages, to support the identity of the Decurions and the *Boni homines*, is explained with greater ease by the supposition, that the place which the Decurions had held, while the population of the cities was exclusively Roman, passed to the wealthier class of the inhabitants, under the name of *Boni homines*, as the two elements were blended, but without any violent change in the constitution. To have destroyed an existing organization, the uses of which were evident, would have argued a love of destruction, which prejudice only can attribute to our Teutonic forefathers; to have submitted themselves to the narrow oligarchal dominion of the Decurions, when they became inhabitants of cities, would have been an abandonment of those principles of equality in the administration of justice, which was one of their strongest and their noblest characteristics.

In maintaining the connexion between the Roman Municipia and the communities of the Middle Ages, Savigny is opposed to some of the French antiquaries, but supported by others. The question was considered as intimately affecting the rights of the crown and the people; and

Dubos in favour of the latter, and Boulainvilliers of the former, pushed their respective doctrines to an absurd extreme. It is observed by Mr. Cathcart, p. 308, that, although in the preface to the 11th volume of the Ordonnances des Rois de France, Vilevault and Brequigny maintain that the *Communes* depended entirely on a royal grant, and originated only in the 12th century, they have considerably modified this doctrine in the succeeding volume, and admit that *communes* arose in two ways, either from new grants, or from royal confirmations of the rights of already associated citizens. The latter occur most frequently in the south of France, where in many cases the royal charters only renewed ancient privileges. It is not unimportant, that in many of the cities of France a tradition prevailed, that their judicial institutions had continued without interruption from the times of the Romans. Thus the citizens of Rheims, in the 12th century, purchased from their bishop the permission to live according to the laws "quibus civitas continue usa est, *a tempore S. Remigii Francorum apostoli*." The same opinion of the high antiquity of their municipal institutions prevailed also in Toulouse, Lyons, Boulogne, Angouleme, &c. Among the Italian antiquaries, however, there is no such diversity of opinion as among

the French. Maffei, Muratori, Lupi and Fumagalli are unanimously of opinion, that the Roman constitutions had entirely perished in the cities, and that we are not to look further back than to the 11th or 12th century for the origin of their liberties. Sigonius and Sismondi assign an earlier date to the revival of municipal freedom,—the reign of Otho I. p. 950, but equally suppose its previous extinction.

The principal arguments, by which Savigny opposes this prevalent belief, are derived from the *Codex Utinensis*, a MS. transferred from the Cathedral of Aquileia to that of Udine, and published by Canciani in 1789 in his great collection of the *Leges Barbarorum*. The basis of it is the Breviarium of the Visigoths, itself a compilation from the Theodosian Code. That it was composed in Italy appears from the frequent occurrence in it of words of Italian formation; its date is more uncertain. Canciani thought that it was composed under the native Lombardic princes, but Savigny, from the frequent use of *fretum* and *admallare*, two words of Frankish jurisprudence, concludes that it must have originated in the times subsequent to the conquest of Lombardy by Charlemagne; and from the mention of both *rex* and *principes*, that it was written when royal

prerogative still existed, but much impaired by feudal usurpation, and therefore between the fall of the Carlovingians and the reign of Otho, or from 850—950. Another eminent jurist, the late Dr. Haubold, of Leipsic, fixes its date at the beginning of the 10th century. Regarding it as a summary of the law of the Lombardic Romans in this age, we find from it that the cities had an independent jurisdiction, and that the fines for evading it were paid to them; that the *Boni homines** elected the judge, by whom this jurisdiction was exercised, and who, in addition to his judicial functions, had the charge of the property and revenue of the city. He administered justice not alone, but in conjunction with the *Boni homines*, in trivial matters; those of a graver nature being reserved for the *Princeps*, i.e. the duke or count or the *seniores principes*, the judges appointed by the sovereign, who however in the true spirit of the German constitution, decided 'cum bonarum personarum judicio.' The existence of a municipal jurisdiction, humble in its objects and limited in its sphere, has thus been traced to within a century and a half of the time, when all admit that the cities of Lombardy possessed free institutions, and within half a cen-

* Savigny every where substitutes Decurions for the Boni homines of the original, agreeably to his own theory.

tury of that, which Sismondi and Sigonius assign to their revival. That the sphere of this jurisdiction was humble was in its favour; affording no ground of jealousy to the feudal rulers, it was allowed to exist in obscurity, till better times brought it forth in revived and increased activity. From the latter part of the 9th to the middle of the 10th century, was a period of calamity to the North of Italy; the factions of the Dukes of Spoleto and Friuli and the inroads of the Hungarians inflicted much deeper wounds than the original invasions of the Goths and Lombards, and it is not wonderful if amidst such confusion it is impossible to trace the history of civic institutions.* One result very important to the ultimate liberty of the cities was, that being no longer defended by the power of the state, they began to arm and fortify themselves.

From the testimony of Sidonius Apollinaris, Ep. iv. 17. 'Rhenanis terris—Latina jura ceciderunt' and from the mention of the Roman law, in the Ripuarian code, only as that 'qua Ecclesia vivit,' it may certainly be inferred that in Cologne and the other Roman cities on the Rhine, the bulk of the inhabitants had ceased

* L'Italie Septentrionale n' a eu presque aucun historien dans le dixiène and l'onzième siècle. Sismondi i. 366.

to be Roman; but there is nothing improbable in the supposition that, subordinate to that of the bishop or archbishop, a municipal jurisdiction may have existed, of the same humble kind as in the cities of Lombardy, though no positive evidence can be produced. However this may be, I think we are warranted to conclude, that at least in the South of France and in the North of Italy, the Roman Law continued to be administered with Roman forms in the cities till nearly the time of their revival; that in less important matters jurisdiction was exercised by magistrates, appointed by the higher class of the citizens and with their co-operation, and that the city property was managed by the same class of persons. We have here then at least the rudiments of a municipality. It remains to be shown, whence that new spirit was derived, which being infused into the cities in the beginning of the 12th century raised all of them to opulence and freedom, some to political independence, and very generally procured them charters, creating or confirming their liberties.

The first impulse towards the improvement of the cities, unless where they were within reach of foreign commerce, must be derived from the improvement of agriculture, which animates the

industry of the manufacturer, by giving the cultivator the means of rewarding it. Till the tranquil possession and even hereditary transmission of land was secured by the firm establishment of law, no great increase of the population of cities could take place. Those of the fertile plains of Lombardy needed only a short interval of peace and regular government to become flourishing; the South of France and the adjacent coast of Spain had suffered little either from the original invasion of the Barbarians, or the subsequent revolutions of the Middle Ages, and had besides been enriched by the commerce of the Mediterranean. Even in England, towards the end of the Saxon times, though agriculture was rude and manufactures of very limited extent, the population of the towns was considerable, and they do not appear to have been generally oppressed either by their sovereign or their immediate superiors. The soccage tenure, which was so general, gave the cultivator on easy terms a secure and virtually hereditary possession of his land. The natural fertility of the Netherlands rivals that of Lombardy, and the population of the cities was increased by the early establishment of woollen manufactures, the great source of wealth to the Western Kingdoms of Europe, before the introduction of silk

weaving from the East. The woollens of Friesland, which then comprehended all the northern parts of the late kingdom of the Netherlands, had been celebrated even in the Frankish times, and Charlemagne is said to have sent a Frisian mantle as a present to a Persian prince.* Cologne appears in the first half of the 11th. century as a place of great commerce, trading with the cities of the Netherlands, as well as with the North, and inland with Germany, and in the year 1074 its merchants are reckoned at more than 600 (Hüllm. i. 158.) Many causes conspired to produce a great developement both of the internal and external commerce of Europe about this time. The influence of the Crusades on the cities of Italy is a nearly exhausted topic. The increasing wealth and power of the Church produced an increase of splendour and costliness in the performance of its ceremonies. The sees of bishops had usually been fixed in cities already of magnitude and importance, but they also contributed greatly to the increase of population and commerce. On the great festivals of the church they were the resort not only of the pious but of the worldly-minded, and, as at the Pas-

* This early celebrity of the Frisian woollens, for which Mr. Hallam, M. A. i. 367 requires an authority, is mentioned, according to Hüllm. i. 221. by the Monachus San-Gallensis. ii. 26. 31.

sover of old, or the assembling of the pilgrims at Mecca, religion and traffic were closely connected. The wares of the merchants were exposed to sale on the outside of the church,* or even within its walls, and while the services of devotion were celebrated in the choir, Jew and Christian chaffered in the nave. Hence so many fairs were held and are still held on Saint's days; hence the very general custom of Sunday markets, which the Capitularies of Charlemagne ineffectually proscribed, while in Hungary this day was expressly appointed for them by law, in order to facilitate commerce. Nüremburg owed its rapid increase to the concourse of devotees to the shrine of Saint Sebaldus; Durham and Winchester prospered from a similar cause. St. Denis near Paris, Corvey, Gendersheim and Quedlinburg in Lower Germany, are examples of abbies, the establishment of which was followed by the holding of markets and fairs, to which merchants from distant parts of Europe resorted. The increase of luxury and splendour in the habits of the great, the costly dresses and finished armour of the knights, not only employed the industry of the domestic manufacturer, but excited the merchant to fetch rare and costly

* Decem mercatores ante portam ecclesiæ manentes, reddunt xl. denarios. Domesday, Berkshire. Abingdone.

articles from distant countries, and diffuse them by inland traffic over the whole of Europe.

Such an increase of wealth was inevitably followed by the desire first of liberty, then of power, in the inhabitants of the cities. The formation of the gilds of merchants and companies of lower tradesmen and artizans, was a most important step towards perfecting those municipal institutions, of which we have seen that the rudiments have been preserved from the Roman times. They are generally supposed to have originated at this time, and Hüllmann (p. 322) assigns as the cause of the formation of gilds, the necessity which the merchants felt of having mercantile causes decided by more enlightened judges than the magistrates of the cities. Yet when we reflect how exactly the gilds and incorporation of trades and handicrafts correspond with the *collegia* of the Romans, which continued in vigour down to the overthrow of the empire, we shall think it not improbable that they had existed, though in a depressed and languishing state, through the dark part of the Middle Ages. A *capitularius* of the merchants is mentioned in a document of the year 953, in Fantuzzi Monum. Ravenn. i. 133. 149. and an incorporated company of fishermen in

one of 943 in the same work, iv. 174. the oldest examples probably on record. The gilds of the Anglo Saxons described by Turner, (iii. 98) were something different; yet it is evident that before the conquest merchant gilds had been formed, since a gildhall at Dover is mentioned in Domesday book, and the charter of Henry II. to the citizens of Lincoln (quoted by Hallam, iii. 31.) if it speak truth, attributes to the gild of that place, a jurisdiction not only over the merchants of Lincoln, but of the whole county. The possession of common property and the administration of it by persons chosen among themselves, was one of the least alarming rights which a community could exercise, and this the burgesses of English cities appear undoubtedly to have possessed before the Conquest. See Sir H. Ellis's Indexes to Domesday Book.

The internal history of the older cities on the continent, is nothing else than that of the successive transfer of power from the sovereign to his secular or ecclesiastical vassal, from him to the nobility, from the nobility to the wealthier of the mercantile class, and from them to the incorporated tradesmen and artificers, till either anarchy ended in despotism, or the sovereign by the recovery of his legitimate authority restored

peace between the contending orders. It is not meant that in every city, or even in every kingdom, the whole series of these changes was passed through; they began and stopped at different points, but such was the general tendency. Originally the supremacy over the cities, whose contributions were almost the only source whence ready money was to be derived, had been carefully reserved by the sovereign to himself, and they were administered by his officers. As a consequence of this, no city could fortify itself without his permission, and during the earlier part of the middle ages they generally remained, more especially in the North of Italy, without any defence, or only surrounded by mounds and palisades. But as the Dukes and Counts became independent of the crown, they took upon themselves to erect or allow the inhabitants to erect walls. In the towns, which Henry the First established throughout the interior of Germany, he obliged the landed proprietors of the adjacent district to reside by turns, in order that they might not want defence; and we find that in some cities of Languedoc and Germany lands were given on military tenure, on condition of residence and service in their defence. In others, especially in the South of France, the citizens themselves possessed lands in military

tenure in the neighbourhood, on condition of serving for the defence of the city, and the whole domain. Such were the 'burgenses honorabiles qui ut milites vivere consueverunt' mentioned in the statutes of Avignon. After the fortification of the cities with walls, however, the citizens began to find that service on horseback was unnecessary for their own defence, and either evaded the obligation, or purchased an exemption from it. The constables, *constaffler*, who are mentioned in some of the German cities, can from their name have been no other than citizens serving on horseback, not however from any feudal obligation, but as belonging to the wealthier classes as distinguished from the artizans. In Lombardy great numbers of the nobility of the districts around the cities, especially the poorer, obtained the rights of citizenship, and by this alliance with the rising power regained some of that importance which they had lost. Besides being entrusted with civil offices, they had generally the command of the military force of the cities, particularly of the gates, and availed themselves of this power to oppress the rest of the inhabitants, till after long struggles and many reverses they were expelled. In some of the German cities, as in Cologne and Erfurt, we find the command of the gates held as an

hereditary office by noble families, and the landed gentry of the neighbourhood obtaining the rights of citizenship, and commanding the troops of the cities. When the artizans in the Italian towns had triumphed, after a long struggle, over the civil aristocracy, the military force was divided according to the companies, each division consisting entirely of those who followed the same handicraft, or if the number of these was too small, several being united, whose occupations had a certain affinity with each other.

The same struggles which in the Italian cities, not being controuled by any sovereign authority, and inflamed by the disputes of the Guelf and Ghibelline parties, were carried on with a violence which influenced the history of Europe, agitated other communities also, though with less conspicuous results. In these the contest regarded chiefly jurisdiction and administration. The *Scabini*, who according to the constitution of Charlemagne were judges under the presidency of the counts, had been chosen by the people, subject to the approbation of the count. This right of participation in the appointment of their judges, however, appears to have been encroached upon, during the time of the depression of the cities, and one of the first wishes of

the citizens, when they began to feel their power, was no longer to be subject to the ignorant or partial decision of a judge who knew nothing of law. The end of the 11th and beginning of the 12th century was the time, when very general efforts were made by the citizens for the recovery of their lost rights in the South of France and in Lombardy. The *consules* who are mentioned in their histories were originally only judges, 'judices consules,' as they are called at Verona; 'consules justitiæ' at Como. The right to fill city offices generally, but more especially the consulate, was claimed to themselves by the old families, who possessing landed property and either following the profession of arms, or engaging only in the higher kinds of merchandise, formed a natural aristocracy in the cities. Besides Lombardy we find traces of this limitation in some of the towns of Provence; but it is most distinctly seen in the imperial towns of Germany, Ratisbon, Nüremburg, Augsburg, and above all Cologne, where the patrician houses maintained their exclusive elegibility till 1396. Along with the *consules*, whose office was soon extended from judging to administration, two councils are commonly found, a smaller, the *Credentia* of the Italian cities, which was an executive body, and a larger, whose

office was legislative, variously denominated *consilium plenum, capitulum,* and in Italy and France *Parlamentum.* The numbers of both varied; of the latter Barcelona affords an example of an assemblage amounting to one hundred, and at an earlier period two hundred. In Italy, from the early independence of the cities, the councils were subject to no controul; in the South of France the meetings of the *parlamentum* usually took place in the palace of the temporal or ecclesiastical lord, and therefore probably under his sanction. In the Italian towns each of the quarters named from the gates elected a certain number of members to the council, as they furnished a certain number to the army; elsewhere, a division according to parishes answered the same purpose. The bishops, who in the older German cities had by this time obtained the feudal superiority, found it expedient not to resist the general demand of the cities for self-government, and the emperors were disposed to favour the citizens against their lords. Frederic the II. after granting a charter to Basel, recalled it (1235) and declared that he would erect no community without the consent of the bishop; but the bishop of Ratisbon having betrayed him to the Pope, he a few years after (1245) revoked his revocation and re-established the rights of the citizens.

It was not without resistance on the part of the older families and wealthier citizens, that the new power of the artizans was admitted to participation in these municipal offices. In some of the cities of Provence, the same method was adopted for the preservation of peace between the contending parties as in Italy; the government of the city was committed for a year to a foreigner, under the name of *Potestas*. In Marseilles, in 1233, six of the masters of companies were admitted every week to be assessors of the council, which was composed of citizens of the higher class, and this continued till 1257, when the new sovereign, Charles of Anjou, excluded the citizens from all share in the administration. In Tarascon the artizans obtained admission, after an insurrection in 1233. In Toulon and Aix, which did not receive municipal constitutions till the 14th century, the different orders were from the first admitted to joint administration. It was in the imperial and episcopal cities of Germany, however, that the weakness of the sovereign power allowed parties to proceed to acts of violence, most nearly resembling those which took place in Italian cities. The butchers and the weavers, the one the fiercest, the other the most numerous, of the companies, usually distinguished themselves by

their activity on these occasions. In Germany, as in Tuscany and in Lombardy, the cause of the lower orders was promoted by the quarrels of the old families among themselves, which made it necessary for some other power to step between and preserve the peace, and which also divided the force which might otherwise have resisted the popular claims. Instead of describing the outrages committed at Cologne, whose history most nearly resembles those of Milan and Florence, it will be more interesting to read what happened at Augsburg, as an example of that wise and timely compromise with a rising power, by which the benefits of change are attained without its evils.

In the middle of the 14th century the old families still kept possession of the government, but beyond the Alps, and in the cities on the Rhine, to which the artizans of Augsburg carried their productions for sale, they saw the men of their own order admitted to the administration, and they determined to claim a similar share. No complaints were made of misgovernment and oppression against the old families; but the time was come, when their monopoly must cease. On the 21st. October, 1368, the companies in arms took possession of the gates

and invested the Rathhaus. The bürgermeisters assembled the council, and some of the members went among the insurgents, who treated them with great courtesy and appointed six of their number to negotiate with them. Their demands were that the old families should give up the administration to the companies, and transfer to them immediately the seal and register of the city, and the keys of the alarm bell, the Rathhaus and the treasury. With the latter demands the council complied; in respect to the administration, it succeeded in convincing the delegates of the companies, that before adopting such an extensive change, it would be prudent to obtain more exact accounts of the 'working' of the constitution in other cities, in which the companies had obtained the ascendancy. This was agreed to; twelve assessors from the artizans were admitted *ad interim* to to the council, and after two months the delegates returned, with the information which they had collected, that no where had the artizans the whole government in their own hands, without any participation of the old families. Their number was at that time fifty-one; that of the companies seventeen; it was agreed that the twelve assessors of the artizans should remain in the council, and one for each company be

added to them with a bürgermeister of the same class, making thirty; the old families sending fifteen. The larger council was also composed of both classes, but with a great preponderance of the companies.

I have hitherto described the changes which took place in the older cities, which derived their origin from the Roman time, and in which therefore it is at least conceivable that a tradition of the Roman municipal constitution had been preserved. In the North of France and the Netherlands, however, a number of towns, which owed if not their existence, at least their importance, to the woollen manufacture which flourished here in the 11th century, when they first obtained a municipal constitution, either placed the artizans on a level with the old families or in the sole possession of power. The feebleness of the sovereign, in the last reigns of the Carlovingian and the first of the Capetian dynasty, the venality of the public officers and the rapacity of the nobles would have left the people without defence, had they not determined to rely upon themselves. The kings were not long in perceiving that they could only hope to re-establish their own authority, on which the great vassals had so deeply encroached, by fos-

tering the growing power of the towns. Sismondi (Hist. des Français 5. 120) and Thierry (Lettres sur l'Hist. de France) have sufficiently exposed the error of the common opinion, which makes Louis le Gros the champion and emancipator of the commonalty, and have gone so far as to doubt, whether in founding or confirming communities, he was influenced by any other motive than a desire to obtain a sum of money for rendering them this service. Yet if we reflect, that the early part of his life was spent in endeavouring to subdue the petty vassals who disputed his authority, we must suppose that he could not have failed to perceive, how much his own power would be increased by the independence of the towns, over which these vassals tyrannized. That he erected no communities on his own domain confirms this view of his policy; and that he sometimes sided with the bishop or the count, against a town which was struggling for emancipation, only proves that the present interest which urged him to accept their bribe, was stronger than the distant motive of increasing his prerogative.

Some of the hardest contests which the communities in the North of France had to maintain for their liberties were against their bishops,

who had here been more completely transformed into feudal lords than in the South of France, and who retained nothing of the spiritual function, except the terrors of excommunication by which they endeavoured to support their tem poral authority. The inhabitants of Laon had formed themselves into a community in the absence of their bishop, who had sworn to respect their liberties, and the king himself confirmed them by a charter. Nevertheless the king not long after joined the bishop in an attempt to annul the institutions which they had granted, and the bishop lost his life in the tumult which this act of treachery excited. Soon after, the principal citizens having abandoned the city in apprehension of the vengeance of the king, the adherents of the bishop came forth from their retreat and put to death all who had been left behind. The king at length interfered, and gave to the city a charter, in which avoiding the name of *commune* he virtually established nearly the same privileges under the title of *institutio pacis*. His successors sometimes confirmed and again annulled these privileges, and sometimes the citizens, sometimes the bishops, were triumphant, till in 1331 the community was dissolved by Philip VI. Rheims had to maintain a similar succession of contests for its liberties.

Noyon was fortunate in a bishop who took the lead in erecting a commune there, and invited Louis VI. to join in confirming it; and the citizens of Beauvais and St. Quentin obtained charters without much difficulty from their bishop and their count. Flanders had been earlier than Picardy the scene of these attempts of the towns to render themselves independent.* In Mons the people had risen as early as the year 1070, and six years later those of Cambrai expelled their bishop from the city. He was reinstated by the aid of the emperor, and again expelled; and for nearly four hundred years the predecessors of Fenelon lived in a state of perpetual warfare with their spiritual charge. These northern cities had greater difficulty in maintaining their liberties against their lords, as their population was chiefly composed of men hiherto unaccustomed to the use of arms, while in those of the South an order of *milites* and *personæ militares* was generally found. The burghers were compelled therefore by turns to handle the shuttle and the spear, and at the sound of the alarm bell, pealing from the bel-

* Bruges and Ghent probably both obtained the right of chusing their echevins, an important part of a municipal constitution, from Baldwin V., who lived between 1034 and 1067. Hüllm. 3. 42.

frey of the commune, to muster in arms for the defence of their walls.

The constitutions of these cities of Northern France and Flanders differed from those of the South and of the Rhine, in bearing stronger marks of feudal origin. The great object was to secure an independent administration of justice, for which purpose the echevinage was formed commonly of twelve members and a *Major* (Maire), who had a civil and criminal jurisdiction except in capital cases, which was reserved for the propositus (prévôt) or bailiff of the superior. In some instances, as at Beauvais, the echevins appear under the feudal name of *Pares*. For the administration of the affairs of the community a council answering to the *credentia* was established, who in France were usually called *jurati*, in Flanders *choremanni*, whence the law of the city itself was called Chora and Keuran;* the most common number was twenty-four, one half being composed of the echevins, the other of the jurati. The larger cities only had also a council, answering to the *parlamentum*

* Kôren signifies to choose, but it is doubtful whether in this connexion it is applied primarily to the magistrates to designate their election, or to law as expressive of the choice and pleasure (wilkühr) of the party who enacts it.

of the South; in Rochelle it consisted of seventy-five members, in Rouen of one hundred; this body, representing the whole of the citizens, chose from its own number the jurati, and proposed to the king three citizens, of whom he nominated one to the office of mayor. Rarely was any distinction made in eligibility to office, in favour of the higher class of the citizens, or of patrician families, and the instances which occur are chiefly in Flanders and Brabant. In Louvain, the old families had almost entirely excluded the artizans from a share in the administration, in consequence of which, in 1378, the latter, headed by the woollen weavers, expelled them from the city. The personal privileges which the inhabitants of the cities gained by their erection into a community were, freedom from illegal seizure of their person, inheritance without seizure by the lord, and exemption from dues and talliages beyond a moderate and stipulated sum. It was an important consequence, in reference to the political character which the towns afterwards assumed, that when they thus withdrew themselves from under the dominion of the bishop or the count, the king considered them as coming immediately under his own jurisdiction as head of the state.* This

* 'Reputabat rex, civitates omnes suas esse in quibus communiæ essent.' Bouquet xii. 304.

the crown lawyers subsequently improved into the doctrine, that it belonged to the king alone to establish a commune, which, like most of the abstract doctrines of prerogative, was a gross historical falsehood.

It is a remarkable feature in the history of England, we speak exclusively of the southern part of the island, that both our personal and our constitutional liberties have been at once more durable than those of the continental nations, and have been gained with far less of violence and bloodshed. Our municipal institutions were not gained in a single instance by those violent collisions between the cities and their feudal lords on the one hand, and the different orders of citizens on the other, which were so common abroad. This difference has arisen from a variety of causes. The cities of England, with the exception of London and one or two others, were of small population compared with those of Lombardy, of Provence and Flanders, and the attempt to render themselves independent would have been equally absurd and fruitless. Before the Conquest the yoke of feudal oppression had been much lighter in England than on the Continent; and though baronial power was greatly increased by that

event, the strength of the crown was augmented in more than an equal degree, and those enormous abuses, which drove the inhabitants of the cities to rebellion, were prevented by the existence of an authority which would at least tolerate no tyranny but its own. The wealth of the cities of England had not been so great as to form a body of patrician families to monopolize municipal office, and the landed gentry, secure in the possession of their property and afterwards admitted as an order to political power, were not driven as in Lombardy to seek refuge in the cities, and there constitute a municipal aristocracy. The *barones** of London and of the Cinqueports were probably only the wealthier citizens on whom expensive and responsible offices naturally devolve.

At the time of the Conquest it is doubtful whether any town or city in England possessed the right of electing its own judges or had advanced further towards the dignity of a corporation, than by possessing land and tenements in common, for the administration of which property some smaller body probably existed with some rule of election. The charter of William the Conqueror to the city of London†

* Matt. Paris 744. † Brady, p. 16.

addressed to William the bishop, and Godfrey the portreeve, only grants to the citizens that they should all be law-worthy as they had been in King Edward's days, i. e. that they should only be dealt with by form of law, the distinction between a freeman and a villein or serf, and that 'every child should be his father's heir after his father's days,' which included an exemption both from the lord's claim to his vassal's property and also from the Norman law of primogeniture. The commutation of the indefinite claims of the lord for a fee-farm rent from the whole borough had begun before the Conquest, and was much extended afterwards, though the right of talliage was still exercised. The 'consuetudines' which William Rufus and Henry I. granted to different cities were to enjoy exemption from tolls and similar burdens, and it is very doubtful whether before the reign of Henry II. any city had received the privilege of electing their own chief magistrate and judge.* The name of mayor seems to imply that the cities of France and Flanders, with which England was so closely connected, had furnished the model on which its municipalities were constructed, as far as the state of the people

* Hallam iii. 36. refers it generally to the reign of John.

allowed the imitation to be carried. Sheriffs whose jurisdiction extended over the county of Middlesex were joined to the chief magistrate, and in the middle of the 13th century the resemblance to the council of the continental cities was completed by the distribution of the metropolis into twenty-four wards, over each of which an alderman presided. A common council corresponded in its composition to the larger council which we have described in France and Germany. The example of London was followed by the other great cities and towns, which between the time of John and Henry III. had very generally purchased immunities and privileges from the crown. The summoning of citizens and burgesses to parliament in the close of the latter reign gave a new character and influence to municipal institutions, which it does not come within our present purpose to trace.

# EXPERIMENTS

AND

# OBSERVATIONS

ON THE

# EFFLORESCING PROPERTIES

OF SOME

# SALTS OF SODA.

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By HENRY HOUGH WATSON,

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Communicated by Dr. DALTON. (Read, March 18th. 1836.)

SODA being extensively used in some of the arts, disputes frequently occur between the manufacturers and the consumers of it with regard to its strength. When, by analysis, the consumer finds it to be of a less degree of strength than it was sold to him for, and to contain a considerable per centage of water; he

is met, on stating the circumstance to the manufacturer, with the reply that he must have allowed the article to acquire moisture from the atmosphere previously to testing it. This assertion is often received by the consumer with discredit, under the supposition that those salts of soda—the Sulphate and Carbonate—of which the article the subject of dispute principally consists being described by scientific writers as *efflorescent* salts, cannot be capable of imbibing water from the atmosphere.

In consequence of a dispute of this kind, I exposed to a red heat a quantity of impure carbonate of soda, such as is used by bleachers: I then put 50 grains of it into a watch glass, and left it exposed to the atmosphere in my laboratory. At the expiration of 23 days I found it to have gained 51 grains of water. This was a convincing proof that some of the anhydrous salts of which this sample was constituted must be capable of absorbing hygrometric water to a great amount; and I was consequently urged to commence a number of experiments, to determine what amount of water the anhydrous carbonate and sulphate of soda are severally capable of acquiring, and to decide under what circumstances they really are efflorescent salts.

Hitherto I have considered those salts which are usually described as efflorescent salts, to be such as would effloresce whenever they were left exposed to an atmosphere which had any drying power; that is, to an atmosphere not saturated with vapour, but capable of evaporating water: and I believe that the same idea is generally entertained on the subject. Now, the result of my investigation furnishes the proof that such an idea is not a correct one: it shows that the crystallized sulphate and carbonate of soda, which are generally considered as very efflorescent salts, may be left exposed to the atmosphere for any length of time without efflorescing in the least or losing a single particle of water of crystallization, though that atmosphere be dry and capable of evaporating water, *so long as its evaporating power is not allowed to extend beyond a certain point*:—this point differs for each salt.

While my experiments were going on, I registered every day the temperature and the vapour point of the rooms in which they were conducted. I give a copy of the registers in a subsequent part of this paper.

In order to find how much water pure anhy-

drous carbonate of soda is capable of absorbing, I, on the 20th October, 1835, put 47.4 grains=1 atom, (supposing the atom of soda to be 28, and that of carbonic acid 19.4) prepared by calcining the bi-carbonate, into a watch glass of known weight, and left it exposed to the atmosphere in a room in which no fire was kept. By frequently weighing the glass and contents I found the gain of weight to be as follows.

| Oct. | Weight gained. | Oct. | Weight gained. |
|---|---|---|---|
| 21 | 3.3 grains. | 27 | 18.6 grains. |
| 22 | 6.1 —— | 28 | 21.1 —— |
| 23 | 9.1 —— | 29 | 23.6 —— |
| 24 | 11.8 —— | 30 | 26.6 —— |
| 25 | 13.8 —— | 31 | 28.6 —— |
| 26 | 16.1 —— | | |

The salt having concreted into a rather hard mass was now broken up, so that it might the more readily acquire more moisture.

| Nov. | Weight gained. | Nov. | Weight gained. |
|---|---|---|---|
| 1 | 31.6 grains. | 3 | 38.6 grains. |
| 2 | 34.1 —— | 4 | 40.8 —— |

The salt was now removed from the watch glass, crushed, and spread over the surface of a dinner plate, so that the process might be sooner finished.

| Nov. | Weight gained. | Nov. | Weight gained. |
|---|---|---|---|
| 6 | 56.1 grains. | 16 | 78.6 gained. |
| 11 | 77.6 —— | 21 | 78.6 —— |
| 14 | 78.6 —— | | |

I left it exposed to the atmosphere till the 4th. December, when I found it to be of the same weight as on the 21st. November. It was therefore evident that more water could not be absorbed.

Now, the 78.6 grains of water absorbed are only 1.4 grains short of being equivalent to ten atoms,* and it is probable that a waste of that quantity of salt may have been made in the numerous weighings. If this be granted, I am right in concluding that the anhydrous carbonate acquires water until it is of the same constitution as the crystallized carbonate, if exposed to such an atmosphere as I have made use of,—one (as will be perceived by the register) whose temperature ranges from 53° to 43°, and whose vapour point is not more than 7° below the temperature nor less than 5°.

In Dr. Dalton's new system of Chemical Phi-

* Or 2.1 gr. short of what, from the result of a subsequent experiment which I shall hereafter mention, I should have expected the gain to have been.

losophy, Vol. 1, part 2nd., under the head *Carbonate of Soda*, he tells us that he found 100 grains of crystals of carbonate of soda by exposure to the action of the atmosphere for eight days to be reduced to 44 grains; and by a red heat to 37 grains. He, therefore, concludes that the ordinary efflorescence of this salt is not dry carbonate, but one atom of carbonatc and one of water. And he offers as a confirmation to his conclusion, the fact that he found his 37 grains of calcined residue to again become 44 grains by exposure to the atmosphere for five days. It is evident from the result of my experiments that he either did not continue his exposure long enough, or that the atmosphere in the case of his experiment had much more drying power than in the case of mine, or he would have found the gain of water to have been much greater. His conclusion, however, very nearly agrees with mine with regard to the quantity of water which can be lost by efflorescence, as will be perceived from the experiments which I shall mention in the sequel.

On the 20th October, I put 100 grains of crystals (broken small) of pure Carbonate of Soda, prepared from the Bi-carbonate, into a watch glass; and left them exposed to the

atmosphere of the same room. The glass and contents were weighed every day for more than a fortnight. By one day's exposure a loss of weight of 2¼ grains was sustained; but, afterwards not the slightest loss took place, even though the exposure was continued till the 4th December, nor was the least efflorescence perceptible from the beginning to the end of the experiment. The crystals retained perfect transparency.

The 2¼ grains of water lost by the first day's exposure was not belonging to the constitution of the crystals: it must only have been sticking about them in consequence of their having been imperfectly dried, notwithstanding that I had previously dried them with blotting paper as well as I thought they could have been.

I have also kept exposed to the like atmosphere for several weeks *a very few* broken crystals *widely spread over a large surface* of glass, but no efflorescence in that case took place.

On the 23rd October, I put 100 grains of crystals of pure Sulphate of Soda, prepared by neutralizing the Bi-carbonate with sulphuric acid, and which I had dried with blotting paper

as well as I thought possible, into a watch glass and left them exposed to the atmosphere of the same room. By the first two days exposure a loss of $2\frac{1}{2}$ grains was sustained; but, afterwards, though the exposure was continued till the 3rd November and the weighing repeated every day, neither loss of weight nor efflorescence was perceived; but the crystals remained transparent. Of course the $2\frac{1}{2}$ grains of loss in this case also must only be the consequence of using imperfectly dried crystals: indeed, as a proof of this may be noticed the fact that while this experiment was going on I placed in exposure to the same atmosphere some *anhydrous* sulphate, and it gained weight. The quantity of anhydrous sulphate exposed was 20 grains; and in 86 days it gained 25.4 grains of water, whereby it was rendered of about the same constitution as the crystallized salt.

When I became aware what were likely to be the results of the experiments I have related, my object was to repeat them in an atmosphere of greater drying power. I therefore left exposed to the atmosphere of a room in which a moderate fire was regularly kept, 20 grains of crystals of Sulphate of Soda, 20 grains of crystals of Carbonate of Soda, and 20 grains of anhydrous

Sulphate of Soda, each in a separate watch glass; the former from the 30th October to the 4th December, and the two latter from the 31st October to the 4th December.

Both these crystallized salts I had previously dried by exposure for a few days to the atmosphere of the room in which the before-mentioned experiments are made.

After one day's exposure it was perceptible that the crystals of Sulphate had begun to effloresce. On the 1st November they had lost $\frac{1}{4}$ of a grain: on the 4th, $1\frac{1}{4}$ grain: on the 11th, $3\frac{3}{4}$ grains: on the 16th, $5\frac{1}{4}$ grains: and on the 4th December, $9\frac{3}{4}$ grains. I now discontinued the exposure; but if I had not done so the crystals would without doubt have lost water until they had become anhydrous.

The anhydrous Sulphate was frequently weighed, and found not to gain any weight.

On the 1st November, the crystals of Carbonate were found neither to have lost weight nor to have effloresced in the slightest degree: on the 5th some of the outside crystals were *slightly* effloresced, which I apprehend must be in con-

sequence of the lowness of the vapour point on the 2nd (11° below the temperature), and also on the 4th (10° below the temperature): on the 11th, these crystals were no more effloresced than they were on the 5th: by the 4th December, however, efflorescence was considerably more apparent, though even then it had not made a great advance: in the interval between the 11th November and the 4th December, the vapour point had several times been 10° and 11° below the temperature; which was undoubtedly the cause of this further efflorescence.

Though this efflorescence, or rather *opacity* of the outside crystals had taken place, *the weight was still the same as when they were transparent*, viz. full 20 grains. This is accounted for by supposing that the crystals lose water only when the vapour point is a certain distance below the temperature, and that they gain back that which they then lose when the vapour point is a less distance below the temperature: or, when the atmosphere is of a certain drying power it robs the crystals of water; and when it is of a less drying power it allows them to regain their loss.

From the 4th November to the 4th December, I had also 20 grains of anhydrous Carbonate of

Soda exposed to the same atmosphere; and, as might have been expected from the result of the experiment on the crystals, this salt gained water. On the 5th, it was found to have gained $1\frac{1}{2}$ grain: on the 11th $6\frac{3}{4}$ grains: on the 16th $9\frac{3}{4}$ grains: and on the 4th December 19 grains: had I continued the exposure, it would undoubtedly have become of the same constitution as the crystals.

The conclusion to be drawn from the results I have now stated, is that the crystals of Carbonate of Soda begin to effloresce at the temperature of 58° when the vapour point is at 48°: and that crystals of Sulphate of Soda begin to effloresce at the temperature of 58° when the vapour point is at 49°: and, therefore, that the carbonate may be left exposed to the atmosphere at the temperature of 58° when the vapour point is not lower than 49°, and the sulphate when the vapour point is not lower than 50°, without any of their water of crystallization being lost: and, since the atmosphere in those states of dryness is capable of evaporating uncombined water, we have beautiful means afforded of providing ourselves with the salts in question free from any water not belonging to the constitution of the crystals, but at the same time with

all that does belong to it; which appears hitherto not to have been a very easy matter; for, on reference to Dr. Henry's Elements of Experimental Chemistry, vol. i, page 594, 11th Ed., we find this expression relative to sulphate of soda —'by exposure to the atmosphere, it effloresces, and loses weight; and with so much quickness that it is difficult to ascertain precisely its water of crystallization.'

I have also in a similar manner examined the efflorescing property of the ordinary phosphate of soda; and, as near as I can judge, it is the same as that of the carbonate.

Register of the temperature and vapour point of the room in which no fire was kept.

| 1835 Oct. | Temperature at noon. | Vapour point at noon. | Nov. | Temperature at noon. | Vapour point at noon. | Nov. | Temperature at noon. | Vapour point at noon. |
|---|---|---|---|---|---|---|---|---|
| 20 | 51° | 46° | 1 | 45° | 39° | 13 | 46° | 39° |
| 21 | 49 | 42 | 2 | 43 | 38 | 14 | 47 | 40 |
| 22 | 48 | 41 | 3 | 50 | 45 | 15 | 44 | 38 |
| 23 | 50 | 43 | 4 | 48 | 42 | 16 | 44 | 38 |
| 24 | 50 | 43 | 5 | 44 | 38 | 17 | 48 | 43 |
| 25 | 47 | 40 | 6 | 46 | 40 | 18 | 53 | 47 |
| 26 | 47 | 41 | 7 | 46 | 41 | 19 | 51 | 45 |
| 27 | 46 | 40 | 8 | 46 | 40 | 20 | 51 | 45 |
| 28 | 47 | 41 | 9 | 46 | 40 | 21 | 53 | 47 |
| 29 | 48 | 43 | 10 | 43 | 38 | | | |
| 30 | 47 | 41 | 11 | 46 | 40 | | | |
| 31 | 48 | 42 | 12 | 47 | 40 | | | |

The vapour point has never been more than 7° below the temperature, nor less than 5°.

Register of the temperature and vapour point of the room in which a fire was kept.

| 1835 | Temperature. | | | Vapour point. | | | | Temperature. | | | Vapour point. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. | Morn. | Noon. | Night. | Morn. | Noon. | Night. | Nov. | Morn. | Noon. | Night. | Morn. | Noon. | Night. |
| 30 | | 58° | 58° | | 49° | 49° | 14 | 51° | 53° | 54° | 43° | 45° | 45° |
| 31 | 56° | 57 | 57 | 48° | 48 | 48 | 15 | 53 | 55 | 55 | 45 | 46 | 46 |
| Nov. | | | | | | | 16 | 53 | 55 | 56 | 45 | 47 | 47 |
| 1 | 55 | 57 | 58 | 47 | 48 | 49 | 17 | 56 | 57 | 57 | 47 | 48 | 48 |
| 2 | 55 | 58 | 59 | 47 | 47 | 50 | 18 | 55 | 63 | 62 | 47 | 52 | 52 |
| 3 | 56 | 58 | 58 | 48 | 50 | 49 | 19 | 57 | 59 | 60 | 48 | 49 | 51 |
| 4 | 55 | 58 | 57 | 47 | 48 | 47 | 20 | 57 | 60 | 60 | 48 | 50 | 50 |
| 5 | 54 | 57 | 57 | 46 | 48 | 48 | 21 | 58 | 59 | 58 | 49 | 50 | 49 |
| 6 | 54 | 57 | 57 | 46 | 48 | 48 | | | | | | | |
| 7 | 54 | 55 | 58 | 46 | 47 | 49 | | | | | | | |
| 8 | 53 | 55 | 55 | 45 | 46 | 46 | | | | | | | |
| 9 | 54 | 56 | 55 | 46 | 47 | 46 | | | | | | | |
| 10 | 54 | 57 | 55 | 46 | 48 | 47 | | | | | | | |
| 11 | 54 | 55 | 57 | 46 | 47 | 47 | | | | | | | |
| 12 | 52 | 57 | 57 | 44 | 48 | 48 | | | | | | | |
| 13 | 53 | 55 | 54 | 45 | 46 | 45 | | | | | | | |

The vapour point has never been more than 11° below the temperature, nor less than 8°.

The vapour point was ascertained by the aid of an hygrometer on the principle of Leslie's, (an abstract of a paper of mine respecting which will be found in the report of the meeting of the British Association at Edinburgh,) though I frequently found it experimentally, to prove the correctness of the instrument.

Supposing that the increase of atmospheric temperature increases the disposition of the water of crystallization to evaporate from salts according to the same law as it increases the disposition of ordinary uncombined water to evaporate,* we shall be able to determine from the result of my experiments and by the aid of Dr. Dalton's table of the force of vapour from water at different temperatures, at how low a vapour point these salts may be exposed to the atmosphere at other temperatures than what my experiments were made at, without suffering a loss of water.

I have stated that I find the crystals of carbonate of soda only *begin* to effloresce at the temperature of 58° when the vapour point is at 48°:

* The capacity of the atmosphere for vapour increases with the increase of temperature, and decreases with the decrease of temperature.

hence then I consider that when the vapour point is only at 49°, the disposition of water to evaporate, or in other words, the affinity of space for vapour, is just equal to the affinity of the salt for its water of crystallization—that then the crystallized salt would not lose water, neither would the proto-hydrate gain water.

I have also stated that crystals of sulphate of soda only begin to effloresce at the temperature of 58° when the vapour point is at 49°: hence I consider that when the vapour point is only at 50° the affinity of space for vapour is just equal to the affinity of this salt for its water of crystallization.

Now, by Dr. Dalton's table* we find that the force of vapour at 58° is equal to 0.62 of an inch, and at 50° to 0.49 of an inch. Then, by deducting 0.47 from 0.62 we have 0.15 of an inch of mercury—the force of affinity with which carbonate of soda holds its water of crystallization.

By adding 0.15 to 0.62 we get 0.77, which we find by the table is the force of vapour at

* I refer to that table in the ii. vol. of his System of Chemistry.

66° of temperature. It consequently follows that at the temperature of 66° crystals of carbonate of soda can only retain their water of crystallization when the vapour point is not lower than 58°. According to this rule are arranged the following columns of figures.

The figures uppermost in each column are the degrees up to which the atmosphere must be saturated with vapour when the temperature is equal to the degrees next immediately below, in order that the salt exposed to that atmosphere shall not effloresce.

| Carbonate of Soda. | Sulphate of Soda. |
|---|---|
| 20° | 30 |
| 38 | 41½ |
| 49 | 50 |
| 58 | 58 |
| 66 | 65 |
| 72 | 70 |
| 77 | 75 |
| | 79½ |

Being afforded such simple means of procuring the salts under consideration with neither more nor less water than what is actually indispensable to their existence in the crystallized state, I was led to investigate the several per centages of water: and in doing so have adopted

the plan of placing the salt, the object of experiment, under an exhausted air pump receiver along with a vessel of concentrated sulphuric acid. By this method we avoid the inconveniences consequent upon the watery fusion which the salts undergo by the immediate application of heat.

One hundred grains of crystals of carbonate of soda put under an exhausted receiver with a vessel of sulphuric acid lose in a few days (temperature ranging from 39° to 45°) 56.8 grains of water. By allowing the salt to remain under the receiver longer, no further loss is sustained: but, by exposing the 43.2 grains of remaining salt to a red heat 6.2 grains of water are expelled, and 37 grains of anhydrous salt are left. This anhydrous salt being put under an exhausted receiver with a vessel of *water* instead of sulphuric acid, rapidly gains water; and in two or three days becomes of the same constitution as the crystals, its weight being 100 grains if no portion has been lost in the manipulations.

One hundred grains of crystals of sulphate of soda by the exhausted receiver and sulphuric acid lose in a few days (temperature about 45°) 56.2 grains of water: the salt remaining is

anhydrous, and weighs 43.8 grains;—it loses no weight by exposure to a red heat. By exposure for a few days under the exhausted receiver with a vessel of water it becomes of the same constitution as the crystals, and weighs 100 grains.

One hundred grains of crystals of phosphate of soda by the exhausted receiver and sulphuric acid lose in a few days (temperature about 45°) 60.35 grains of water. By allowing the salt to remain under the receiver longer, no further loss is sustained; but, by a red heat the 39.65 grains of remaining salt are reduced to 37.1 grains. This anhydrous pyro-phosphate being put under the exhausted receiver with a vessel of water gains water rapidly, and in a day or two weighs 66 grains; after which it gains no more weight:—but if the salt when not calcined, but merely dried by the action of the exhausted receiver and sulphuric acid till its weight is 39.65 grains, is submitted to the same treatment it gains water till its weight is again 100 grains.

The crystals of all these salts by losing their water lose their transparency and their hardness; but when they are allowed to regain their water, whether from the open atmosphere or

under the receiver, they do not regain their transparency though they all regain their hardness, with the exception of the pyro-phosphate which only does so to a slight amount. If, however, dew happens to fall upon them they do regain their transparency, and to an amount proportionate to the quantity of dew which falls upon them. If an exhausted receiver having a vessel of water under it suffers a reduction of temperature, by being in a room whose temperature is allowed to fall, a precipitation of dew takes place within it; and this falling upon the salt, the object of experiment, not only has a tendency to bring back its transparency, if it has already got its full quantity of water of crystallization, but renders it damp:—if this is allowed to take place in the instance of pyro-phosphate of soda that salt does not even then take into combination any more water than I have described; for, if to dry it, it be exposed to an atmosphere whose drying power is not sufficiently great to cause efflorescence all the excess of water evaporates.

I apprehend that the circumstance of anhydrous sulphate of soda gaining water till it becomes of the same constitution as the crystallized salt may be taken advantage of in analysis.

It is sometimes a desideratum to ascertain if and to what amount *muriate of potash* (an article much used in the manufacture of alum) is adulterated with muriate of soda. The means which would hitherto be used to accomplish that object are tedious. If, however, a solution of a sample of the kind in question be treated with *sulphate of ammonia* till all the muriate of the fixed alkali is converted into sulphate, and the resulting mixture be evaporated to dryness, and calcined till all the ammoniacal salt is dissipated, the residue will be the anhydrous sulphate of the alkali of the sample: and by placing it under an exhausted receiver along with a vessel of water we shall be able to ascertain whether it is entirely sulphate of potash or a mixture of that salt with sulphate of soda:—if it is all sulphate of potash it will gain no permanent weight however long the experiment is continued, since water is not a constituent part of the crystals of that sulphate; but if there is any sulphate of soda present it will gain weight till that portion becomes of the same constitution as it is of when it exists in the crystallized state.

# A MEMOIR
## OF THE
# LIFE AND WRITINGS
## OF THE
# LATE DR. HENRY,

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By WILLIAM CHARLES HENRY, M.D., F.R.S. and F.G.S.

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(Read January 13th, 1837.)

In attempting to present to the Literary and Philosophical Society, some memorial of their late vice-president, and of his eminent services to science, the writer feels, that he must rely entirely on their considerate and most indulgent sympathy. He is conscious, that the habits and impressions of his whole life scarcely consist with an impartial portraiture of one, to whom

he stood in the nearest human relation, and whose sacred image must ever dwell on his memory as a noble impersonation of all that was pure, generous, and elevated. Yet he is also sensible, that this near affinity and the unreserved communion of thought and of feeling, which it permitted, lay open the sources of more accurate knowledge of character, and kindle a more intense perception of excellence, as respects both the gifts of the understanding and the virtues of the heart. The gratifying kindness, moreover, with which the society were pleased to invite him to prepare such memorial, encourages him to believe, that they will receive it in the same spirit of affection, which they have, in various ways, so strongly manifested towards the memory of their lamented associate and friend.

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THE late Dr. Henry was born in Manchester, on the 12th of December, 1774. His early years were passed amid influences, propitious to the nurture of those tastes, for which he was afterwards distinguished. His father, Mr. Thomas Henry, F.R.S. formerly president of this society, was a zealous cultivator of chemical science, to which he devoted all the leisure moments of a life actively engaged in medical practice,

with a perseverance and success that have been affectionately commemorated by his son.* The earliest impressions of Dr. Henry's childhood were, therefore, such as to inspire interest and reverence for the pursuits of science; and he is said, when very young, to have sought amusement in attempting to imitate with such means as were at his disposal, the chemical experiments, which his father had been performing. A severe accident, which befel him in early life, by disqualifying him for the active sports of boyhood, must also have contributed to determine his taste for books and sedentary occupations. This injury, occasioned by the fall of a heavy beam upon his right side, was so serious as at the time to endanger life and materially to check his growth, and left as its consequence acute neuralgic pains, which recurred often after long intervals of remission, and with peculiar severity some months before his death. His fortitude, while yet a child, in supporting the sudden paroxysms of pain, which were often so intense as to oblige him to rest in the streets, was most remarkable;—and in his efforts to banish the perception of physical suffering by an absorbing mental occupation, he already manifested

* Manchester Memoirs. 2nd. Series, vol. iii.

that energy of resolution and purpose, which throughout life compelled a feeble bodily frame to keep pace with the exertions of an ardent and unfatigued spirit.

Dr. Henry's earliest instructor was the Rev. Ralph Harrison, whose repute, as a teacher of the ancient languages, was so widely spread, as to draw to Manchester the sons of persons of rank from a distance, and among others, those of the Marquis of Waterford, attended by their accomplished tutor Mr. de Polier. On the establishment of an Academy in Manchester, which has since been removed to York, Mr. Harrison was chosen to fill the chair of classical literature. His pupil had made such rapid progress as to be permitted, though considerably under the customary age for admission, to follow his preceptor to this enlarged sphere of competition. Here, though struggling with older and more advanced classmates, his diligence and ardour were rewarded by the approbation of his Academic superiors, and he received in the prize allotted to him—an elegant copy of Virgil—the earliest of those literary distinctions, which, throughout life, constituted the main objects of his ambition.

Immediately after leaving the Academy, Dr.

Henry had the good fortune to succeed Dr. Holme as an inmate in the house of that accomplished scholar and enlightened physician the late Dr. Percival. A constant liability to violent headaches, combined with weak eyesight, prevented Dr. Percival from writing or reading with the vigour and continuity essential to his various literary pursuits. It was the duty therefore of Dr. Henry and of other young persons, who occupied the same place before or after him, to read aloud to Dr. Percival, and to conduct, after his dictation, the extensive correspondence, which he maintained with those most eminent in science and in letters. Dr. Percival's style was peculiarly correct and elegant; and his example and judicious counsels seem to have been most instrumental in guiding the tastes of his young companion, and in establishing habits of vigilant and appropriate expression. Dr. Percival also directed with great judgment and kindness his course of reading, and particularly recommended to him works on mental and ethical philosophy;—thus probably laying the foundation of that taste for enlarged speculation on the moral and intellectual nature of man, and of that faculty of delicately discriminating the finer shades of character and of genius, which contributed so largely to his sources of enjoy-

ment and of fame. Of the salutary influence upon his character, of such intimate communion with this learned and high-minded physician, he was accustomed often to speak in after life with grateful remembrance; and was ever ready to pay his warm testimony to the varied and tasteful scholarship, the enlarged philosophy, and the pure and elevated moral bearing of his distinguished instructor. In a letter, many years ago, addressed to the writer, Dr. Henry speaks of Dr. Percival as "an illustrious pattern of every thing delicate and pure in sentiment, elegant and dignified in taste, and polished in address and manner:—a man who while he would have adorned a court by his gentlemanly demeanour, yet paid a tender and unceasing attention to the feelings of the humblest of those, by whom he was habitually surrounded."

In this improving residence, Dr. Henry remained during five years, which were devoted to the general culture of his mind, and to the preliminary studies of his profession. About the close of this period he first engaged in the practical observation of disease in the Manchester Infirmary, where he enjoyed the instructions of another of those eminent physicians, who

have conferred so much literary glory on this town and on this society, the late Dr. Ferriar. In his invaluable "Medical Histories," the systematized records of his experience in our great public charities, Dr. Ferriar, has left to the profession, the finest existing models of what such narratives of disease ought to be—in style; simple, concise, and energetic, though not rejecting on suitable occasions (as in his moving essay on the Treatment of the Dying) the warmer colouring suggested by deep feeling;—in substance; deriving general pathological conclusions, from the accumulated and methodized results of an experience no less ample than sagaciously directed and interpreted. As a hospital physician, Dr. Ferriar seems to have possessed, in an eminent degree, the faculty of at once eliciting truth from the obtuseness or reluctance of the suffering poor, by his abrupt and pointed interrogatories, and by his impatience of all irrelevant matter. He was especially distinguished by strength and rectitude of understanding, by manners perhaps somewhat unbending and severe, by a high sense of honour, and by a fearless and dignified moral bearing. To his pupil, his manner was always friendly and encouraging;—and out of this early intercourse issued the sources of mutual

esteem and permanent friendship, which were strongly evidenced, by his confiding, during illness, his medical duties to Dr. Henry, and also by his making choice of him as his own attendant in the successive seizures which preceded his death.

After having been thus initiated in those pursuits, to which his after life was to be mainly dedicated, Dr. Henry was removed in the winter of 1795-6 to the University of Edinburgh, at that time in its highest repute as a school of medicine and of the natural sciences. The chair of Chemistry was still occupied by the venerable Dr. Black, whose discovery of the facts, that establish the existence of heat in a latent form, and whose successful discrimination between the caustic earths and their carbonates, had raised him to the highest rank among chemical philosophers. Dr. Henry was an eager hearer of the beautiful prœlections, in which Dr. Black, with calm and simple dignity, unfolded in exact and perspicuous order, the truths of a science, which may almost be said to have been first called into existence by himself and his contemporaries. Dr. Henry's early kindled love for science was strengthened by lessons so impressively taught, in which, reverence for the teacher was inter-

woven with intense delight in the subject matter of his instructions, and, especially, with a glowing admiration of that successful inductive process, which had guided to the discovery of Latent Caloric. Dr. Henry was no less fortunate in his other instructors, both in general and professional knowledge. The important chair of Practical Medicine was then filled by Dr. Gregory, whose marked originality of thought and humour, and whose happy talent of arresting attention by illustrative cases, narrated with dramatic effect, threw around the descriptions of disease a fascinating interest, to which they would seem naturally most alien. On Dr. Henry's second visit in 1805 to the University, he found the chair of Physical Science adorned by the profound mathematical learning of Playfair, and that of Moral Philosophy occupied by Stewart, whose pre-eminence as a teacher has been beautifully celebrated by the most competent judge of modern times.* Of the invaluable instructions of Mr. Stewart, Dr. Henry was prevented from availing himself by the necessity of following at the same hour some professional lectures; but he has confessed that he not unfrequently deserted the Clinical Theatre for the impressive

*Sir James Mackintosh, Preliminary Dissertation, p. 386.

lessons of a higher wisdom. He ever retained and expressed the deepest admiration for the compositions of these two master minds. The style of Playfair, in his Dissertation on Physical Science, and in his biographical notices of Hutton and Robison, Dr. Henry regarded as upon the whole the best adapted to philosophical purposes, which our language possesses, and he had certainly erected it into a standard for his own imitation. In the writings of Stewart he was accustomed to praise the delicacy and correctness of his taste in arts and letters, the easy and melodious flow of his periods, his graceful distribution of ornament; but above all, the elevation and purity of his moral judgments and sensibilities, and the fervour and depth of conviction, with which he ever advocates as inseparable, the interests of philosophy and of virtue.

To this period of his life, Dr. Henry always looked back, as a season of pure and unmingled happiness, arising out of the consciousness of a steady and rapid progress in knowledge, undisturbed by the cares and practical business of life, and quickened by constant intercommunion with minds ardently devoted to similar pursuits. He seems, indeed, to have been peculiarly happy in his intimate associates and

fellow-labourers. Nor has the Metropolis of the North ever before or since assembled within its Halls of Science, either so many illustrious teachers, or so noble a company of hearers. Among the latter were numbered Marcet, Roget, De la Rive, Thomson, Allen, Scarlett, and Jeffery; and Lord Brougham, as a youthful disputant in the Speculative, and occasionally in the Physical and Medical Societies, was giving evidence of those native energies of genius and character, which have since borne him to the highest judicial and political station in this country.

Breathing such an exciting atmosphere, and urged onwards by his own ardent spirit, Dr. Henry devoted his entire time and strength to mental improvement; and has often affirmed that the rest of his life, active as it was, appeared a state of inglorious repose, when contrasted with this season of unremitted effort. It was, therefore, with deep regret, that after a year thus spent, he quitted the University, in deference to prudential considerations, with little prospect of ever revisiting it as a student; and engaged in association with his father in general medical practice. After a few years experience, however, the inadequacy of his delicate frame to bear up against the fatigues of this branch of

the profession became evident, and he was permitted, in the year 1805, to return to the University, where he received in 1807, the diploma of "Doctor in Medicine."

The period intervening between his two academic residences, though passed in the engrossing occupations of his profession, to which was added the superintendence of a chemical business, many years before established by his father, was yet marked by several important contributions to science. In 1797, he communicated to the Royal Society, an experimental memoir, the design of which was to re-establish,—in opposition to conclusions drawn by Dr. Austin, and sanctioned by the approval of Dr. Beddoes and other eminent chemists,—the title of carbon to be ranked among elementary bodies. His proofs were derived from the electrization of an impure carburetted hydrogen gas: but it is needless to particularize the experiments, since in a subsequent paper, he made known a source of fallacy, which had vitiated their results. They have value therefore, chiefly as suggesting encouragement to the young, by showing that Dr. Henry had to pass through a stage of tentative initiation before reaching the consummate skill, which afterwards distinguished him in that most delicate province of chemical research.

In the same interval (1800) he also made public through the Philosophical Transactions, some experiments on the Muriatic Acid Gas. This memoir is one of peculiar interest, both as recalling the state of chemical doctrine, anterior to the grand discoveries of Davy, and as marking the influence of pre-conceived theories on the interpretation of facts. Oxygen was then regarded as the sole principle of acidity, and the muriatic acid was consequently supposed to be constituted of oxygen, associated with an unknown radical. It was in the hope of detaching this imaginary element from oxygen, that Dr. Henry exposed the muriatic acid gas, both alone, and mingled with gaseous matter possessing a strong affinity for oxygen, to repeated electrical discharges. When the muriatic acid gas was electrified alone over mercury its volume was uniformly diminished, hydrogen gas was disengaged, and a white deposit was collected, which proved to be calomel. The decrease of volume and the formation of calomel were much more considerable, when the electric discharges were passed through a mixture of oxygen and muriatic acid gas. When the electrization was performed without the presence of mercury, in a glass tube, closed by stoppers, each perforated with platina wire, chlorine was evolved

and detected by the usual test. It is manifest that these experiments, had they been justly interpreted, were sufficient to establish the true view of the composition of muriatic acid gas. Yet governed by the theory of acidification then universally prevalent, Dr. Henry referred the disengagement of hydrogen to the decomposition of water, which was supposed to be still present in the gas after a week's contact with fused chloride of calcium. Nor was it until many years subsequently that the simpler theory was firmly established by the genius of Davy. To the new doctrine, Dr. Henry, had, however, the merit of becoming an early convert; and in a supplementary essay, published in the Transactions for 1812, he supplied some important evidence in its favour. He showed that the same proportion of hydrogen gas was obtained by electrizing muriatic acid gas, whether it had been exposed or not to fused chloride of calcium; and hence concluded that the hydrogen was eliminated from the muriatic acid gas, and not from aqueous vapour. He also ascertained, that the muriatic acid gas, when completely insulated in a closed glass vessel, sustained no change of volume from a succession of electrical discharges. This permanence of bulk was made more apparent by repeating the experiment in a vessel with a neck

of only one-fifth of an inch in diameter. After admitting water to absorb the undecomposed muriatic acid, there remained one hundred measures of chlorine and one hundred and forty of hydrogen. In conformity with the law of Gay Lussac, the quantities should have been equal, but the deficiency of chlorine was justly referred to its large absorbability by water. The perfect accordance of muriatic acid gas with the law of volumes was further shown by the observation that the contraction of volume in muriatic acid gas electrized over mercury;—a diminution due to the combination of the liberated chlorine with mercury,—is precisely equal to the quantity of hydrogen gas obtained.

In 1803 Dr. Henry made known to the Royal Society his elaborate experiments on the quantity of gases absorbed by water at different temperatures and under different pressures. The absorbabilities of the different gases, under a constant pressure, by water of 55° Fahrenheit, were first accurately measured. Elevation of temperature was found to lessen the amount of absorption, the diminution for each increment of 10° above the standard temperature being equivalent to about $\frac{1}{14}$th of the entire bulk absorbable at 55° Ft. In investigating the absorp-

tion of the same gas under varying pressures, Dr. Henry arrived at the simple law "that water takes up of gas condensed by one, two or more additional atmospheres, a quantity which ordinarily compressed would be equal to twice, thrice, &c., the volume absorbed under the common pressure of the atmosphere." This exact proportionality, of the quantities absorbed to the pressures, makes strongly in favour of the theory proposed by Dr. Dalton, that the absorption of the gases by water is due entirely to mechanical agencies.

Dr. Henry described in the Philosophical Transactions for 1808, a form of apparatus, adapted to the combustion of larger quantities of gas than could be fired in eudiometric tubes. Results were thus obtained, which may be pronounced fair approximations to truth, especially when estimated with reference to the still imperfect resources of pneumatic chemistry. The apparatus cannot however be now recommended when extreme precision is desirable. In this year, 1808, he was elected a Fellow of the Royal Society, and in the following year received by the award of the President and Council, the medal on Sir Godfrey Copley's donation, as a mark of their approbation of his

various papers communicated to the society and printed in the Philosophical Transactions.

The same analytical method by which the decomposition of muriatic acid gas had been effectuated was in 1809 employed by Dr. Henry to resolve ammonia into its constituent gases. These experiments may even now be commended as models of extreme accuracy. Ammoniacal gas previously dried with great care, was found to expand to double its primitive volume after a sufficient number of electrical discharges. The average of eight experiments (in five of which the volume was exactly doubled) gave the relation of 100:198.78 between the volumes of gas before and after decomposition, a conformity between theory and experiment, which modern refinement cannot surpass. In this memoir Dr. Henry also made known a remarkably elegant and expeditious method of analysing ammonia, by firing it in a volta tube with a deficient quantity of oxygen. In this process all the ammonia is decomposed, though a part only of the hydrogen thus liberated meets with its equivalent of oxygen. More oxygen is then added to burn the residuary hydrogen:—for Dr. Henry had observed, that if the whole quantity of oxygen was added at once, the results were

disturbed by the production of nitrate of ammonia. In estimating the proportion of hydrogen and nitrogen constituting ammonia, he obtained somewhat less hydrogen than the theoretical quantity, a deficiency which he rightly ascribed to the cooling agency of so large a volume of azote causing a part of the hydrogen to escape unburned. He afterwards by employing nitrous oxide instead of oxygen, obtained and published in the Memoirs of this society, results that establish precise multiple relations.

The gaseous substances, issuing from the destructive distillation of coal and oil, had very early engaged Dr. Henry's attention, and he had at various times devoted much labour both to their chemical analysis and to ascertain their respective fitness for the purposes of illumination. The general conclusions, which he had made known in several successive memoirs, were that these gaseous products are mixtures of olefiant, carbonic oxide, carburetted hydrogen and hydrogen gases in varying proportions, with other accidental impurities, as carbonic acid and sulphuretted hydrogen. An opposite doctrine had been proposed to the Royal Society by a distinguished chemist. It was maintained, that carburetted hydrogen does not

constitute a distinct gaseous species, that olefiant gas is the only known compound of carbon and hydrogen; and that the gases obtained from oil and coal are nothing more than mixtures of olefiant with simple hydrogen.

In an elaborate paper published in the Transactions for 1821, Dr. Henry succeeded, however, in establishing the soundness of his original views. He contended that the concurring results obtained by Dr. Dalton, Sir H. Davy, Dr. Thomson and himself, from the analysis of carburetted hydrogen collected both from stagnant water and from the coal measures, at distant times and places, clearly demonstrate that gas to be a true chemical compound, characterized by perfect uniformity of properties and composition. He proceeded to investigate the action of chlorine both upon carburetted hydrogen and olefiant gases, with a view to learn how far chlorine may be depended upon as a means of effecting their separation. Carburetted hydrogen was found to be wholly unaltered by prolonged contact with chlorine, when light was carefully excluded. Under the same circumstances olefiant gas on the contrary was entirely removed by chlorine. Hence he derived a simple and beautiful mode of separating olefiant gas

from the other gaseous compounds of carbon with hydrogen or with oxygen, as well as from pure hydrogen. After establishing the perfect accuracy of this process, on artificial mixtures of the gases in known proportions, he applied it to the mixtures of the same gases in unknown proportions, which constitute oil and coal gases. The best oil gas showed forty per cent of a gas condensible by chlorine; the best coal gas not more than thirteen per cent. The residuary gases, left after the complete action of chlorine, were then detonated in a volta tube with oxygen, and afforded results, showing that they were mixtures of carburetted hydrogen, carbonic oxide and hydrogen gases, in proportions which he was then unable to determine except by approximative calculation.—"No one instance, he concludes "has ever occurred to me of a gas obtained from oil or coal, which after the action of chlorine upon it, with the exclusion of light, presented a residuum at all approaching to simple hydrogen gas."

In his latest communication to the Royal Society, (1824) Dr. Henry succeeded in conquering the only remaining difficulty in the analysis of these complex mixtures; viz., the ascertaining by chemical means, the exact pro-

portions, which the gases, left after the action of chlorine on oil and coal gas, bear to each other. For this purpose he skilfully availed himself of the property, which had been recently discovered by Döbereiner in finely divided platina, of determining gaseous combination. Having ascertained that carbonic oxide with oxygen is rapidly converted into carbonic acid, in presence of platina at a temperature of 340° Fahrenheit, while carburetted hydrogen is wholly unchanged, till the heat considerably exceeds that of boiling mercury, Dr. Henry exposed a mixture of carbonic oxide, hydrogen, and carburetted hydrogen with oxygen, into which platina had been admitted, to the temperature of 340°. The carbonic oxide and hydrogen were converted into carbonic acid and water,—and their relative proportions easily determined. The residuary carburetted hydrogen was then detonated with oxygen in a volta eudiometer. The numbers thus obtained corresponded precisely with the quantities of the gases that had been mingled together. In further trial of this new mode of operating, it was applied to the analysis of a mixture of the same gases, but in unknown proportions, which constitutes an inferior quality of coal gas. The specific gravity of this gas, derived from the

proportions thus ascertained of its constituents, was .303, a number coinciding as nearly as could be expected with the actual specific gravity of the gas .308.

In the course of this enquiry, Dr. Henry noticed the curious property of gaseous interference, which was observed about the same time, and first made public by Dr. Turner. Though not affecting the main object of his researches, these phœnomena attracted his attention by their singularity and novelty; and the experiments, he performed in the hope of unfolding their nature, suggested a theory of interference, which has been confirmed by recent investigations.—"The property," he observes, "inherent in certain gases, of retarding the action of the platina sponge, when they are added to an explosive mixture of oxygen and hydrogen is most remarkable in those, which possess the strongest attraction for oxygen; and it is probably to the degree of this attraction, rather than to any agency arising out of their relations to caloric, that we are to describe the various powers, which the gases manifest in that respect."

An Essay on the Compounds of Nitrogen,

published in the Manchester Memoirs for the same year (1824), though not adding any facts of moment to the prior results of Gay Lussac, yet made known some new and exact methods of speedily decomposing nitrous oxide and nitrous gas. Thus the constitution by volume of nitrous oxide, was determined with singular precision by detonating it with carbonic oxide, instead of with hydrogen gas; and nitrous gas was found to form an explosive mixture with olefiant gas.

It is worthy of remark, that all Dr. Henry's scientific memoirs, which have been hitherto enumerated, are devoted to the chemistry of aeriform bodies. For this refined department of science, Dr. Henry always manifested the strongest predilection. Indeed of nine experimental papers, contributed by him to the Royal Society, no fewer than eight are dedicated to the gases. At the period when Dr. Henry's interest was first awakened for philosophical pursuits, the rapid discovery by Priestley of several new gases, and the sanguine hopes inspired by Beddoes of detecting in these subtle and hitherto concealed forms of matter powerful remedial agents, urged both physiologists and chemists to engage with ardour in pneuma-

tic researches. Subsequent experience has demonstrated, it is true, the unsoundness of these projects for enriching with new resources, the art of practical medicine. But the beautiful law, unfolded by the genius of Gay Lussac, that the gases combine in volumes which are either equal or multiples by an integral number, —by establishing, when interwoven with the Daltonian philosophy, the existence of some simple relation between the numbers of atoms existing in equal spaces of aeriform matter, has almost elevated the pneumatic chemistry to the dignity and exactitude of a mathematical science. There is, moreover, in the pursuit of these subtle elements, which escape the visual sense, which can be imprisoned and weighed only by the most refined instruments, and which can be discriminated only by the most delicate processes and indications, a somewhat of mystery and of a higher initiation, which deeply moves the imagination. It may too be safely affirmed, that Dr. Henry's habits of extreme mental accuracy, his unrivalled manual expertness, and the general tendencies of his tastes towards elegance and precision, peculiarly qualified him to excel in conducting such delicate enquiries.

But although his original efforts in chemistry were mainly directed to the gases, he was by no means a stranger to other provinces of experimental research. His comparative analyses of many varieties of British and Foreign Salt, were important in refuting the prejudices, then widely prevalent, of the superiority of the latter for certain economical purposes. His Essay on the Materiality of Heat, published in the Memoirs of this learned body, is written with force and perspicuity, though in modern times the tide of doctrine undoubtedly sets in the opposite direction. His critical memoir on the theories of galvanic decomposition has even lately been noticed with praise by Berzelius in his Jahrsbericht, as among the first to assert that view, which in his judgment is still most deserving of adoption. But of the soundness and extent of Dr. Henry's acquaintance with general chemistry his "Elements" furnish undoubted proof. This work, which in 1829 had passed through eleven editions, has always held a high place in public estimation, as a clear and faithful record of the details of chemistry, and as conveying in its general chapters, a distinct and comprehensive survey of the leading doctrines and higher philosophy of the science.

Although impelled by a strong predilection to the pursuit of chemical science, Dr. Henry was not an inactive member of the profession, to which he belonged. Besides contributing to the medical journals of the time, such interesting cases of disease as fell under his observation, as physician to the Manchester Infirmary and other public charities, he engaged in an elaborate investigation of that important class of maladies, which affect the urinary system,—the exact diagnosis of which is well known to rest on indications purely chemical. His inaugural discourse on uric acid; his analyses of many varieties of calculi; and his Essay on Diabetes, were favourably received by the profession, and are still cited with approbation by our best pathologists. Even after having relinquished the exercise of medicine, he continued to feel a deep interest in its advancement, and on a late occasion when the ravages of Asiatic cholera in neighbouring countries suggested the necessity of preventive measures on our own coasts, he established by experiments, as satisfactory perhaps as the nature of the enquiry admitted, the destructibility of various contagious poisons by degrees of heat, inferior to the boiling point of water. It is due, however, to his philosophical caution to state, that Dr. Henry regarded these

experiments only as initiatory and as demanding the confirmation of multiplied and varied trials, before being adopted as the basis of legislative enactments. His feelings of interest had been so deeply excited in the laws and higher physiology of contagion, that he embodied all the facts and evidences he had been able to glean from a most extensive course of reading, in a Report which was communicated to the British Association, and has been published in their Transactions.

Dr. Henry's compass of thought and interest was not however restrained within the limits of his profession and his favourite branch of knowledge. Of the sciences of classification, he had cultivated in early life, with great zeal, both botany and mineralogy; and had formed a creditable collection of mineral specimens. This latter study naturally led him into the kindred pursuit of geology. Indeed, his first academical residence in Edinburgh coincided with the memorable period, when the two rival theories were the objects of constant and eager controversy in all societies, and especially in the higher scientific circle, in which Dr. Henry had the privilege of moving. Shortly after the formation of the Geological Society of London, Dr.

Henry was admitted a Fellow; and though he never aspired to collect by personal research, materials for the advancement of that science, yet he diligently possessed himself of all that was successively made known, and deeply sympathized in its prosperous fortunes and high destinies. During the latter years of his life, especially, these pursuits ministered largely to his sources of enjoyment, and prompted him to undertake several short journeys, with the object of examining interesting sections, and of collecting characteristic fossils. The growing literature of a science, that has attracted to itself so large a share of the intellect and genius of this country, replaced as an object of interest in Dr. Henry's mind, the contemporary progress of chemistry, from the details of which, in consequence of physical inability for experimenting, he had ceased to derive much pleasure.

In polite letters, Dr. Henry had ever been accustomed to seek variety and relaxation from severer study. His range of interest was singularly comprehensive. He took peculiar delight in narratives of voyages and travels, and from such works was in the habit of gathering and preserving all novel facts, that tended to throw light on the physical history of the earth,

or the manners and mental habitudes of its inhabitants. He has thus strongly expressed his sense of the value and dignity of such personal labours and perils in the cause of science. "No subject within the compass of human knowledge embraces so wide a sphere of enquiry, or so much tends to gratify an enlightened and liberal curiosity, as voyages and travels undertaken with a right aim and by persons qualified to reap their rich and varied fruits. To those engaged in them, are offered all the fascination of novelty, all the hopes of wider and brighter prospects of the moral and natural world; all the warm impulses of an honourable ambition to live beyond the present times, and to be remembered by conquests more glorious and more useful than those of the field. These high motives kindle and keep alive a spirit which sustains them through toils, difficulties and disappointments, and enables them to triumph over physical privations and pains, which would dishearten the stoutest if encountered in the every day transactions of life." Biography, especially that of men devoted to the pursuits of philosophy, always occupied him most agreeably,—carrying back his intellectual sympathies to distant periods, and supplying him with materials for after-thought and speculation. His

mind had been early nurtured with the choicest fruits of our national poetry:—and the same purity of taste and affections, which in music made him peculiarly accessible to the simpler melodies, guided him to the fresh and gentle beauties of our earlier poets. He often commended as a happy imitation of their manner, "the Castle of Indolence," a poem, which he more than once read to his domestic circle, with that delicacy and truthfulness of intonation which are inspired only by deep and intuitive perceptions of excellence.

In determining the literary merits of the works of others, and still more in the expression of his own thoughts, Dr. Henry was guided by a correct, or rather a severe taste, which might have rendered him over-fastidious; had not his critical judgments been attempered by the fervour of his sympathies and by the comprehensiveness of his mental vision. An enemy of redundancy in expression or in ornament, he erased in the vigilant revisals, through which all his compositions had to pass, every superfluous term, reaching finally as complete condensation of style as was consistent with ease and distinctness. In strictly philosophical writing he was frugal from principle in the employment of imagery; aiming

solely at the simple and logical enunciation of truth. But in his literary essays; in his biographical notices, when warmed by the contemplation of genius or virtue; and especially in his letters, when his feelings had been touched by the works of nature, or when surveying the grand lines and general bearings of science, and shapingforth his future course, as a philosophical enquirer or writer, his style received embellishment and warmth from a powerful yet chastised imagination, and from a heart prone to generous and noble emotions. His eloquent delineation of the intellectual features of his great contemporaries, Davy and Wollaston;—his enthusiastic homage to the soaring and creative genius of Davy and his no less truthful picture of the opposite endowments,—the caution, the sobriety and precision of Wollaston, are probably fresh in the minds of many present; and may recal Mr. Playfair's celebrated contrast of Black and Hutton, both in many qualities common to the minds compared, and in the vigour which characterizes alike both comparisons. An earlier essay by Dr. Henry, entitled Cursory Remarks on Music, may also be commended as a fine example of the gracefulness and purity of his style, when handling topics of elegant letters.

Dr. Henry appears indeed to have been eminently fitted both by natural tastes and by after culture, to excel in what may be called the literature of science; comprehending especially under that term, the history of discovery and the didactic exposition of general laws and doctrines. In his latter years, he seems himself to have strongly felt, in the perception of growing infirmities, that his season of active research was gone by, and to have looked around for some worthy object, not demanding personal exertions, to occupy what remained to him of life and of mental strength. His thoughts had dwelt for some time on two scientific projects, for both of which he had made considerable preparations. One of these designs, which had floated longest before his mind, and which he was most inclined to realize, was a work that should assemble the beneficent provisions in the Chemical Economy of Nature, which establish the existence and attributes of an All-wise Governor of the Material Universe. He has thus expressed, in a letter addressed many years ago to the writer, his conceptions of the scope and dignity of such an undertaking. "It has always appeared to me a defect in physico-theological works, that too frequent appeals are made to the reason, in proof of divine wisdom, and that

their efficacy is weakened instead of being confirmed by needless iteration. It is enough if a writer, on a subject full of these proofs, presents them first apart from each other, and then in combination, in clear, plain and unaffected language, to the understanding of the reader, and contents himself with a general but forcible impulse towards the conclusions respecting their causation, which have forced themselves upon his own mind. A work of this kind, executed as it ought to be, would be a foundation for a just reputation to its author, and for a more durable one than can be raised by any abstract of the state of technical chemistry, which however well executed at the time, must soon be rendered obsolete by the rapid march of discovery, while the great and leading principles of chemical philosophy will stand unimpeached and unchanged landmarks to guide those, who are in search of truth. There would too, I think, be great utility in such a work, because independently of all such tendency as that to which I have alluded, it would place the reader on a station from whence he might enjoy a distinct view of the surrounding world, of that world with which he is brought closely into contact, and with which he is every hour conversant, but whose most beautiful arrangements

he passes unheeded by. What a wide field of phenomena, for instance, admit of explanation by the laws respecting heat;—the effects of its expansive power both on bodies themselves, and in rendering them its vehicles to distant regions, borne on the waters and the air, which envelope our globe—the influence of the provision of latent heat in retaining it in great storehouses, where it is felt only for good and from whence it issues in continued and vivifying abundance when the sun withdraws his warmer beams—all that relates to the radiation of caloric through infinite space, and its reception by the subjects of the mineral, the vegetable, and the animal kingdoms;—the admirable contrivances especially, by which the latter are cheered and animated, without injury even to the most delicately organized. Surely these are topics (and they are but a very small portion of the whole) on which no man can expatiate without that pure delight, which truth first breaking through ignorance or error, sheds over the mind, refining and exalting both our moral and intellectual natures."

The other literary project, for which Dr. Henry had also collected some materials, was a history of chemical discovery from the middle

of the last century, and devoted in largest measure to the glorious epoch of Scheele, Cavendish, Black, Priestley, and Lavoisier. As the historian of his favourite science, it was Dr. Henry's design to have pursued the method so successfully traced by Sir James Mackintosh in his invaluable dissertation on Ethical Philosophy—that of developing the progressive advances of the science through the lives and triumphs of its most eminent cultivators. The biographical notice of Dr. Priestley, made public in the first volume of the Reports of the British Association, was to have formed one of this gallery of historical portraitures. Such objects, and especially the calm retrospect of the advances of knowledge, and the deliberate estimate of the services of genius, Dr. Henry conceived to be the appropriate employment of advancing years, which, while they chill the active energies of invention and creation, ripen the judgment and incline to contemplative habits, to which they minister the accumulated materials of past study and experience. The evening of life, he often remarked, was far from ungenial to maturity or even vigour in composition, and he readily assented to the similar sentiments so eloquently enforced by Sir James Mackintosh, when characterizing the autumnal fruits of Mr. Stewart's genius. It

is matter of deep regret, that Dr. Henry was not permitted to execute this great design; for, as a writer, it may safely be pronounced that he was never more happy than in his power of discriminating the finer intellectual distinctions, and of painting vivid yet not overcharged mental resemblances. Maintaining an enlarged communion with all orders of intellectual greatness, and an enthusiastic worshipper of genius in all its manifestations, he delighted in thus offering to it his fervent homage, and in giving worthy expression to the intenseness of his feelings and convictions, and to the ardour of his sympathy in every discovery, that promised to advance the well-being of mankind, and to further the cause of universal truth and science.

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To the members of a Society, who as a body have already placed on record their affectionate respect for his memory, and with some of whom he had maintained throughout life, an unbroken friendship, cemented by kindred tastes and mutual esteem, it can scarcely be necessary to offer any detailed portraiture of his moral excellencies. Yet there were some traits rather of manner than of character, which by those not

in habits of close intercourse with him, might not perhaps have been always rightly interpreted. Thus there was occasionally a reserve of manner that might be regarded as implying coldness of feeling, but which arose solely out of the languor produced by an almost constant state of bodily indisposition, and increased by those habits of studious application from which he could never be induced to relax. Though not liable to acute maladies or to such as seemed to endanger life, he had to struggle with what is perhaps less supportable, an habitual infirmity of health and feelings of oppression arising from the slow and imperfect action of the digestive functions. These distempered sensations he was accustomed to lament, mainly as abridging his season for intellectual labour, and especially as disqualifying him for original thought and composition.

In the general intercourse of society, Dr. Henry was distinguished by a polished courtesy, by an intuitive propriety, and by a considerate forethought and respect for the feelings and opinions of others;—qualities issuing out of the same highly-toned sensibility, that guided his tastes in letters, and that softened and elevated his whole moral frame and bearing. His com-

prehensive range of thought and knowledge, his proneness to general speculation in contradistinction to detail, his ready command of the refinements of language, and the liveliness of his feelings and imagination rendered him a most instructive and engaging companion. To the young, and more especially to such as gave evidence of a taste for liberal studies, his manner was peculiarly kind and encouraging. He was most anxious to promote, as far as was in his power, their progress in knowledge, and on one occasion cheerfully dedicated a considerable portion of time to initiate some young friends in those more refined operations of analysis in which he was so consummately skilled.

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From this imperfect record of Dr. Henry's original labours in science, and of his tastes in letters and in philosophy, a more faithful impression of his intellectual habitudes and endowments may perhaps be gathered, than from any general mental analysis. In science, it will have appeared, that his efforts are mainly characterized by ingenuity and elegance in devising instruments and methods of research, and by extreme skill and precision in their employment. But in measuring the amount and importance

of Dr. Henry's contributions to chemical knowledge, it must be borne in mind that in his season of greatest mental activity, he never enjoyed that uncontrolled command of time, and that serene concentration of thought, which are essential to the completion of great scientific designs. His intellectual seedtime was encroached upon by the duties of an extensive medical practice, and by other equally pressing avocations, and his experimental enquiries were conducted at late hours or at intervals snatched from engrossing pursuits and with the liability to constant interruptions. In more advanced life, when relieved from such exertions, growing infirmities and failing bodily power restrained him to studies not demanding personal exertion, and even abridged his season of purely mental labour. That amid circumstances so unfriendly to original and sustained achievements in science, he should have accomplished so much, bears testimony to that energy of resolve, that unsubdued ardour of spirit, which ever glowed within him, urging him steadily onwards in the career of honourable ambition, and prompting exertions more than commensurate with the decaying forces of a frame that had never been vigorous.

Though, moreover, the science of chemistry undoubtedly held the highest place in Dr. Henry's sphere of knowledge and interest, any measure of the strength and compass of his mind, which should rest simply on his chemical acquirements and discoveries, would be eminently inadequate. In forming such estimate, it is essential to his just intellectual station, that regard should be had to the soundness and extent of his knowledge in various branches of physical and natural science, in the advancement of which he had no design of actively participating, and to which he was attracted by no other motive, than the delight he experienced in the varied exercise of his faculties, and in the perception of new truths. Nor would it be just to overlook his rare endowments as a philosophical thinker and writer, the clearness and fidelity with which he assembled and methodized the scattered fruits of discovery, and the simplicity and vigour which characterize his exposition of general doctrines. It would appear, indeed, from some slight notices of his early occupations, which are still preserved, that, at the very outset of his career, he had projected a scheme of study remarkable for its comprehensiveness; having probably, even then, arrived at the conviction, that an equable development

of the various faculties, active as well as speculative, is most conducive to sound mental discipline and to individual well-being; and that a commanding survey of the kingdoms of nature, and enlarged sympathies with the creations of human thought and genius, are wisely purchased by the sacrifice, if necessary, of a somewhat higher degree of excellence in a single department of knowledge.

In conclusion, it may be permitted to one so near to him in blood and in affection, to indulge the conviction, that faculties so vigorous and excursive, so amply furnished with materials for the illustration and enforcement of truth, might, had they been reposited in a less frail tenement, have raised some enduring memorial of their compass and energy;—if dedicated to the history of science, impartially weighing and recording the services of individual minds, yet with vigilant and subordinate reference to the general intellectual movement of each epoch; from which even genius itself derives its primitive impulse if not its special direction;—or if aspiring to trace the footsteps of design in the Economy of Nature, ascending from the loftiest generalizations and most comprehensive laws to the contemplation of the Great Fountain of all truth and of all science.

The writer has been permitted by the President and Council of the Literary and Philosophical Society, to add the following extract from the minutes of the society.

"At the Quarterly Meeting of the members of the Literary and Philosophical Society of Manchester, held October 21st, 1836; it was moved by Dr. Holme, seconded by George W. Wood, Esq., and resolved unanimously, 'That a Special General Meeting of the members of this society be convened without delay, to consider the most desirable method of testifying their respect for the memory of the late Dr. Henry—their profound sense of the benefits derived by the society from his many valuable communications, and from his services, during a long period of years, as Secretary and Vice-President—their high estimation of the distinction which his name as a man of science conferred on the society—and their grateful recollection of the urbanity and kindness, with which he presided at their meetings, shared in their discussions, and promoted both in this society, and on all other occasions the interests of literature, science, and the arts.'

"At a Special General Meeting summoned,

in conformity with the foregoing resolution, on November 2nd, it was resolved, that application be made to Sir Francis Chantrey to execute a bust of the late Dr. Henry, to be placed in the Philosophical Society's apartments, provided the means should be found to exist of obtaining a likeness, and the committee be appointed to make the necessary enquiries of Sir Francis Chantrey, and to report the result of the conference to a future meeting of the society.

"In consequence of this resolution, a correspondence was opened with the distinguished artist alluded to, which terminated in his offering to undertake the execution of the bust on terms, the most honourable to his own feelings, and to the lamented memory of the deceased, and which drew from the society an unanimous expression of its most cordial thanks."

# REMARKS ON FOUR EXTRACTS

FROM THE

# COMMENTARIES OF CESAR,

RELATIVE TO THE USE OF GREEK LETTERS

BY THE

# GAULS AND DRUIDS.

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By the Rev. WILLIAM JOHNS.

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Read November 13th, 1829.

My object in the following Remarks is to correct a mistake, which, I apprehend, most of the Commentators have committed, and to ascertain what use the Gauls, and the Druids both of Gaul and Britain, made of the Greek letters, *literæ Græcæ.*

The history of Cesar's campaigns in Gaul and Britain are well known; and his Commentaries, which contain the account of them, are deemed of great importance not only to the soldier, but also to the historian and antiquary. With the glory of great victories, whatever that may be,

Cesar was not content. His writings are a more imperishable monument of his fame. The effects of his victories are too remote to be perceived, but the value of his writings will never diminish. They are a gift for ever to the human race.* Ages after the demolition of the Roman empire itself, they remain an invaluable acquisition, which no political revolutions or change of dynasties can affect. Of the countries of Gaul and Britain he is the first writer from whom authentic information can be derived on topics connected with their history, geography, institutions, opinions and modes of living. And if from the ambiguity of expression, the brevity of detail, or the necessary obscurity of antiquity, difference of opinion concerning the sense of any passages have arisen, it is the legitimate province of criticism to discover the true interpretation.

I will now cite the extracts, on which any remarks are offered, and annex the English translation of Duncan.

### First Extract: Lib. i. 9.

In castris Helvetiorum tabulæ repertæ sunt

* κτημα εις αει.

litteris Græcis confectæ, et ad Cæsarem perlatæ; quibus in tabulis nominatim ratio confecta erat, qui numerus domo exisset eorum, qui arma ferre possent; et item separatim pueri, senes mulieresque.

## TRANSLATION.

"A roll (rather, *tablet*) was found in the Helvetian camp, written in Greek characters, and brought to Cesar. It contained a list of all, who had set out on this expedition capable of bearing arms; likewise of the children, women and old men."

## SECOND EXTRACT: Lib. v. 48.

Ibi ex captivis (Cæsar) cognoscit, quæ apud Ciceronem gerantur, quantoque in periculo res sit. Tum cuidam ex equitibus Gallis magnis præmiis persuadet, uti ad Cæsarem epistolam deferat. Hanc Græcis conscriptam litteris mittit; ne, intercepta epistola, nostra ab hostibus consilia cognoscantur.

## TRANSLATION.

"There Cesar learnt from some prisoners the

state of the siege, and the danger the legion was in. Immediately he engages a Gaulish horseman, by the promise of great rewards, to carry a letter to Cicero (the commander of the legion.) It was written in Greek characters, that if it fell into the enemies' hands, it might not be intelligible to them."

### Third Extract: Lib. vi. 14.

Magnum ibi numerum versuum ediscere dicuntur: itaque nonnulli annos vicenos in disciplina permanent; neque fas esse existimant ea litteris mandare, quum in reliquis fere rebus, publicis privatisque rationibus, Græcis litteris utantur. Id mihi duabus de causis instituisse videntur; quod neque in vulgus disciplinam efferri velint; neque eos, qui discunt, litteris confisos, minus memoriæ studere: quod fere plerisque accidit, ut præsidio litterarum, diligentiam in perdiscendo, ac memoriam remittant.

### Translation.

"There (where the youths are prepared for the discipline and profession of the Druids,) they are taught to repeat a great number of verses by heart, and often spend twenty years

in this discipline: for it is deemed unlawful to commit those things to writing; whereas in almost all other things, their private and public affairs, they make use of Greek characters. They seem to me to follow this method for two reasons: —to hide their mysteries from the knowledge of the vulgar, and to exercise the memory of their scholars; which would be apt to lie neglected, had they letters to trust to, as we find is often the case."

## Fourth Extract: Lib. i. 19.

Itaque priusquam (Cæsar) quidquam conaretur, Divitiacum ad se vocari jubet, et, quotidianis interpretibus remotis, per C. Valerium Procillum, principem Galliæ provinciæ, familiarem suum, cui summam rerum omnium fidem habebat, cum eo colloquitur.

### Translation.

"Before he, therefore, took any further steps in the affair, he sent for Divitiacus: and having removed the usual interpreters, addressed him through C. Valerius Procillus, a prince (or chief) of the province of Gaul, his intimate friend, in whom he reposed the greatest confidence."

The expression *litteræ Græcæ* in the above extracts is ambiguous, and may signify either the Greek characters or elements, or the Greek language and literature; and this has rendered it necessary to ascertain the author's meaning from collateral circumstances, and the probability of the case. In the result, however, the Commentators have failed to agree in opinion: some think that the Gauls and Druids wrote only the Greek letters, but others that they used the Greek language. Those who have adopted the latter opinion grant at the same time, that the knowledge of it was confined to the *ingenui*,—men of family and influence,—and to the Druids or priests.

It is contended by those, who think that the use of the Greek language itself was meant to be asserted by Cesar, that the expression in question is rendered in the Greek metaphrasis by the word Ελληνιστὶ, which cannot mean the Greek elements, but tongue.

But the Greek translation is of so late a date and so indifferently executed,* as to be of little

* Of this Davis says, in the preface to his edition—"Quicunque demum sit auctor, linguam Latinam minus calluit & a vitiosis codicibus est deceptus: unde factum ut a Cæsaris mente passim aberrarit, et sensum procuderit ineptum."

or no authority. Duncan's authority might be less unobjectionably quoted, who translates the words *litteræ Græcæ* by *Greek characters.*

It is urged, besides, that the Greek colony from Phocis, which founded Marseilles some centuries before the overthrow of the Roman republic, diffused among the Gauls the knowledge of the Greek language, and a taste for the Greek literature. This argument is sustained by a reference to a passage in the Geography of Strabo.* I offer the following as a close translation of as much of the passage in question as relates to our subject:—

"Of which the present state of Marseilles is a proof. For there all persons of a cultivated mind are devoted to eloquence and philosophy. So that that city has of late afforded the barbarians a school of instruction, and induced the Gauls to apply to Greek literature; so that they even wrote their contracts in the Greek language. And the state of learning at Marseilles, at this present time, (that is, in the reign of Tiberius,) has induced the most distinguished of the Romans for their love of philosophy to

* Geogr. p. 248, Edit. Falcon. Oxon.

resort there, rather than to Athens. Following the example of whom, and being at the same time not engaged in war, the Gauls devoted themselves to the same pursuits."

This passage may, at first sight, appear to countenance the more common interpretation; but when all the circumstances of the case are examined, it gives it no support. Strabo published his Geography about sixty years after Cesar's wars in Gaul. In that interval a great improvement had taken place in the civil condition of the Gauls. through the influence of their subjection to the Roman sway; for by the judicious but rigid exercise of power, the Romans soon changed the intellectual and moral condition of the barbarous nations subjugated by them. But during their barbarous state, before their subjugation by Cesar, they were too constantly engaged in wars and turbulence, foreign and domestic, to render it at all probable, or indeed possible, that Strabo's description of the state of things could be applicable to them at that period; and the very words of Strabo sufficiently guard us against such an application. For if the Gauls had been acquainted with Greek literature before the time of Cesar's wars, the expression "of late," or "short time before;"

(μικρῷ πρότερον) could not have been used. The Gauls were never at peace before the invasion of the Roman Triumvir; and the changes which followed after his conquests required a considerable time to be consolidated—to change them from warlike tribes into peaceable husbandmen and cultivators of learning. Accordingly he says, that the change had but lately taken place.

It may be presumed perhaps, that the Gauls would be glad to avail themselves of the neighbourhood of a Grecian colony, so long settled at Marseilles, to acquire the knowledge of letters, and receive the rudiments of civilization. But many circumstances render such a presumtion improbable. The number of the colonists was inconsiderable; and it does not appear that they extended their limits, or acquired any influence on the affairs of Gaul. They were situated at the remotest extremity of the country. Their neighbours were constantly at enmity with them, as we learn from Justin.* With the remoter tribes they could have no communication. The state also of the various nations of

* See Lib. 43, cap. 5. It is true that Justin says, that the Gauls learnt many of the arts of life from the Greeks; but his language is general and, evidently, rhetorical.

Gaul almost necessarily precluded the communication of knowledge and letters. The Gauls were barbarians, and according to the known character of men in that state, their inaptitude for intellectual cultivation was so great, that it required a very long period to be overcome. Before it could be overruled, their general condition must have been changed.

The Gauls had much stronger political motives to make themselves masters of the language of Rome than of Greece, even previously to the wars of Cesar in Gaul; and the acquisition might have been made with, at least, equal facility. But of that language, too, they appear to have been mostly ignorant, for recourse was continually had to interpreters.

It is a well ascertained fact, that the progress of civilization is exceedingly gradual and slow, when it is impelled only by its own momentum. We, however, know, that the Roman power, whereever it was established, took the most decisive measures to accelerate its progress, especially in regard to a few particulars, of which language was one of the principal. We must acknowledge, according to the most undeniable historical evidence, that, from whatsoever

source the Romans derived their arts and institutions, it was through their medium that the arts and pursuits of civilized life were conveyed to these western countries of Europe. Soon after they had acquired a native consistency among themselves, they imparted them, in the course of their conquests, to the half barbarous tribes of Gaul, Britain, and, subsequently Germany, as *their own* productions; and their paramount influence is felt to this day, and will ever be prevalent, in the materials and structure of our languages, in our modes of thinking, in the elements of the sciences, in our works of art and taste, and in our arts of life. And of the circumstances and events of the times, previously to the auspicious change, very little is known, and scarcely a wreck is left behind.

It is much more probable, when all the circumstances are considered, that the Gauls and Druids used, in some cases, the Greek characters in writing their own language, than that, in their position, they should have acquired the knowledge of a language so copious and difficult as the Greek.

Barbarians always borrow their alphabetical characters from others. There is a great de-

gree of affinity between most known alphabets in existence and the first system of which we have account. The Greeks derived their alphabet from the east, the Romans from the Greeks, and all modern Europe from the Romans.

When Cesar began his career of conquest, the Gauls were rude and ignorant barbarians. Before the end of the reign of Augustus, they had made considerable progress in knowledge and civilization. It is not easy to conceive how, previously to the former period, a small colony of Greeks, situated in a remote corner of the country, could have communicated a knowledge of the Greek language to the nations of Gaul, much less of Britain, amidst their continual tumults, dissensions and wars: with habits too, unused to literary pursuits, and in circumstances where neither the value of literary attainments could be appreciated, nor proficiency in them be practicable. In the time of Strabo, it is true, their condition was much improved. But it is inadmissible to reason from facts existing in the the reign of Tiberius, as if they belonged to the time of Cesar.

Several inferences drawn from the extracts themselves, render it highly probable, that by

*litteræ græcæ* Cesar meant only the Greek letters or alphabet, and not the Greek language.

In the first Extract it is only asserted, that the names and numbers of all, who had gone out on the expedition into Gaul, were written on tablets, in Greek letters. From this no conclusive argument can be derived on either side. Names and numbers have not much relation to language. The use of the Greek language, even if we suppose it to have been used, in the mere expression of names and numbers, must have been exceedingly confined. Had the Helvetii, the rude inhabitants of the northern side of the Alps, been acquainted with the Greek language, (an acquisition then not general even among the Romans) Cesar would have probably informed us, whence they had derived their knowledge of it; but the mere use of the Greek letters was not thought worthy of a particular explanation.

In the second Extract we are told, that Cesar wrote to one of his lieutenants, Q. Cicero, who was besieged by the Gauls, a letter in Greek—*Græcis conscriptam litteris**—by a Gallic horse-

* The expression in the first Extract is, *tabulæ litteris Græcis confectæ;* here in the second, *Epistolam Græcis con-*

man; lest, if the letter should be intercepted, his plans should become known to the enemy. It is scarcely necessary to observe by the way, that Cesar and Cicero were well versed in Greek. From this extract then it is easy to be inferred, that by *litteris Græcis* is meant the Greek language; and also that that language was not known to the Gauls; otherwise Cesar could not conceal his designs from the enemy by making use of it in his dispatch. For though in the first instance the letter might fall into the hands of the ignorant, it would doubtless be soon conveyed to some of the *ingenui*, or superior class,—those who have been supposed to possess the knowledge of the Greek language.

From the third Extract it appears to me, that the inference is direct and almost unavoidable, that the Druids wrote the Celtic language in Greek characters. The twenty thousand verses, which were required to be committed to memory, were undoubtedly rehearsed in that language. Yet they were these very verses which they were not allowed to write *litteris*

*scriptam litteris;* and in the third, it is, *litteris Græcis utuntur.* I derive no argument from the difference of expression—*confectæ, conscriptæ* and *utuntur*—because I am not sure it could be sustained.

*Græcis*—in Greek letters—lest the matter they contained should be disclosed to the people.

It seems they recorded their public and private transactions in *Greek letters*; but they were prohibited from committing the Druidic lore to writing in the same manner—"to hide their mysteries from the knowledge of the vulgar," or mass of the people.—But the mass of the people, as before observed, were not acquainted with Greek; and it is scarcely possible to conceive, how they could acquire the knowledge of it, although it was not by any means difficult to write their own language in the Greek characters.

We infer from the fourth Extract, that Divitiacus, the Eduan, was ignorant both of the Greek and Latin languages; for Cesar was under the necessity of holding a conference with him through an interpreter. This, I presume, is the same Divitiacus, who is mentioned by Cicero in the treatise, De Divinat. LIB. I., c. 41. He was, therefore, a person of the highest rank, and also a Druid; and his country was not so distant from Marseilles as most of the other kingdoms of Gaul. We are also informed that Orgetorix, the Helvetian chief, was intimately

connected with the family to which Divitiacus belonged, having given his daughter in marriage to his brother Dumnorix; and it is not probable, that their literary attainments were of a different order.

It may be said perhaps, that Cesar held conferences with the Helvetian ambassadors without interpreters: see ch. VII of B. 1. But the intervention of interpreters on ordinary occasions, is seldom mentioned; and it would not have been noticed in the case of Divitiacus, but for the peculiar nature of the circumstances. Cicero in speaking of conferences with the same Divitiacus, gives no intimation of the use of interpreters; and yet if he was ignorant both of Latin and Greek, they were certainly indispensible.

These facts abundantly confirm our interpretation of the expression *litteræ Græcæ,* as used by Cesar in the Extracts above given; and also prove, I think demonstratively, that if the noble Druid, Divitiacus had any knowledge of Greek, it was only of its first elements or letters, for the purpose of writing his own language.

# AN ACCOUNT

OF SOME

EXPERIMENTS MADE TO DETERMINE THE SPECIFIC GRAVITIES

OF THE

# STEAM OR VAPOUR

FROM

# WATER—ALCOHOL—ETHER--PYROXILIC SPIRIT—AND ACETIC ACID.

By WILLIAM HADFIELD.

Read October 18th, 1833.

It is well known that water and other liquids, when heated sufficiently begin to boil, or throw off an elastic fluid called steam or vapour. The phenomena are well exhibited by heating water in a florence flask, half filled, until it boils. When in brisk ebullition, the steam issues from the neck invisible till it is condensed into small drops by the low temperature of the surrounding air. In a Torricellian vacuum also, aqueous

vapour, or steam is equally characterized by perfect transparency, and it has a degree of force, varying with the temperature, by which it resists the pressure of the atmosphere. This is easily shewn by sending up a drop or two of water, ether, &c. into the vacuum of a barometer. The mercury will descend instantly by a quantity greater or less according to the nature of the liquid and the temperature, without any regard to the height of the barometer at the time.

At the temperature of 60° water will depress the mercury half an inch; ether thirteen inches: and these depressions will be the same, whether the barometer be high or low; in fact an elastic steam instantly arises from the liquid and fills the vacuum, exerting its due elasticity on the mercurial column.

If heat be applied to a barometer in such circumstances, the liquid which has been passed up being wholly converted into vapour, there is an increase in the volume of the vapour, which follows the same law as that which regulates the expansion of air in like circumstances. But when an excess of liquid is present, every degree of temperature adds fresh vapour to that

previously existing, and thus perplexes the result. Hence arises the necessity, when we investigate the specific gravity of vapour, of operating upon it when perfectly secluded from contact with its appropriate liquid.

In determining the specific gravity of any elastic fluid, four things are essentially necessary to be ascertained: viz. *the volume,—the pressure,—the temperature,* and the *weight.* The specific gravity is the weight relatively to the weight of some other standard elastic fluid when both are taken of the same *volume,—pressure,* and *temperature.* The effects of volume, pressure, and temperature upon the weight are well known and can be allowed for when one or all of these three data vary from the standard, as in practice frequently occurs. The vapours of water, alcohol, ether, pyroxilic spirit, and acetic acid are all compounds; the first of oxygen and hydrogen, the last three of oxygen, hydrogen and carbon. The specific gravities of the three first-named vapours have been determined by Gay Lussac and by other eminent chemists, with whose results I have found my own to agree, except that in general I have made the vapours a little heavier than their results.—The differences may possibly arise from errors of

experimenting; though I took all possible care to avoid any source of fallacy, and repeated the trials on each vapour severally, in order that the errors (if any) might compensate each other. I may observe also in favour of my results that I had great advantages in obtaining a high and steady temperature, by reason of a room capable of being heated to any degree between 200° and 250° Fah.; the chamber which is sixteen feet square, and nine feet high, formed of iron bars, three inches asunder, and beneath at the distance of nine feet is the stove for heating it.

Before I began my experiments, I had no knowledge whatever of the methods practised by other experimentalists. My experiments on the vapours of pyroxilic spirit and acetic acid are, I believe, the first that have been obtained. The apparatus which I employed consisted of a glass tube with a ball at the end; the tube being 42 inches long, with a bore of $\frac{3}{10}$ of an inch. The capacity of this tube is 4.64 cubic inches, and that of its ball 3.46, making together 8.1 cubic inches. In some cases I used a similar tube 40 inches long, and having a bore of nearly $\frac{4}{10}$ of an inch. Its capacity is 6.08 cubic inches, that of the ball, 4.3 cubic inches, making together

10.38 cubic inches. To ascertain the exact capacity, the ball was first filled with mercury, and the weight of the fluid then ascertained.

The tube was then filled and the additional weight of mercury determined. I next calculated how many grains of water the ball and tube would contain, the specific gravity of the mercury being considered 13.5, this was determined with each instrument, the trials being made independently of each other, and the weights found to agree. The tube and ball having been well cleaned, carbonate of potash previously made red hot, and put into a small tube of filtering paper, was introduced into the open end of the tube, which was then inverted into a cup of mercury. It was suffered to remain in this situation until the mercury stopped rising in the tube. The ball and tube were then filled with mercury, well boiled, and poured while hot into the tube through a paper funnel dried for the purpose. When filled, every bubble of air was carefully detached by a slender strip of whalebone: the tube inverted into a basin of mercury was of course a barometer, the comparative accuracy of which was judged of, comparing it with a good standard instrument.

A small glass bulb was prepared and its capacity determined by weighing it when filled with mercury. It was then filled with the liquid under examination, care being taken not to put in more than would be vapourized. This being done it was again carefully weighed and passed (the tube standing in a basin of mercury) up into the vacuum above; the basin and the tube containing the mercury were now attached to a wooden frame. A scale graduated to inches and tenths was attached on one side of the tube, and a thermometer on the other side, and the apparatus was now removed into the room before described, in which the temperature was at first 200° and rose gradually for three days until it became 250°. To secure a uniform temperature in the instrument it was suspended in the middle of the room out of the reach of all currents of air.

### Vapour of Water.

The forty two inch tube was used: the capacity of which is 4.64 cubic inches.

| | |
|---|---|
| 3.46 | capacity of the ball. |
| 8.10 | TOTAL. |

The water sent up was 0.666 grains.—The weight of 100 cubic inches of steam, and the specific gravities are calculated at a temperature of 60° and pressure of 30 inches of mercury. Atmospheric air being 1.

*Twelve Experiments.*

| Length of the tube filled with vapour. | Pressure. | Temperature. | Weight of 100 cubic inches. | Specific gravity. |
|---|---|---|---|---|
| inches | inches. | degrees. | grains. | |
| 30 | 19.45 | 204 | 19.41 | .626 |
| 29.9 | 19.05 | 198 | 19.71 | .636 |
| 29.8 | 18.95 | 196 | 19.79 | .638 |
| 30.3 | 19.70 | 222 | 19.70 | .635 |
| 30.4 | 19.80 | 224 | 19.57 | .631 |
| 30.5 | 19.80 | 230 | 19.72 | .636 |
| 30.5 | 19.80 | 230 | 19.72 | .636 |
| 30.8 | 20,20 | 243 | 19.60 | .632 |
| 30.85 | 20.25 | 244 | 19.56 | .631 |
| 30.75 | 20.15 | 236 | 19.47 | .628 |
| 30.50 | 19.90 | 229 | 19.59 | .632 |
| 30.45 | 19.85 | 228 | 19.77 | .637 |
| 30.39 | 19.74 | 233.77 | 19.63 | .633 |

Mean calculated from mean length of tube filled with vapour and mean temperature and pressure } 19.62 gr.
.633 s. g.

When the deduction is made for the expansion of glass and mercury from the given mean,

the weight of 100 cubic inches of aqueous vapour, temperature 60° and pressure 30 inches will be 19.43 grains, and its specific gravity, air being 1 will be .626.

## Vapour of Alcohol.

The 40 inch tube was used in these experiments, the capacity of the tube 6.08 cubic inches, and the capacity of the ball 4.3 cubic inches, making together 10.38 cubic inches, specific gravity of the alcohol .816. Two grains in measure equal 1.632 grains in weight, were sent up the tube.

*Nine Experiments.*

| Length of the tube filled with vapour. | Pressure. | Temperature. | Wt. of 100 cub. inches temper. 60° and pres. 30 in. mean. | Specific gra. of vapour. |
|---|---|---|---|---|
| inches | inches | degrees | grains | air = 1. |
| 25.50 | 16.55 | 202 | 46.96 | 1.51 |
| 25.25 | 16.51 | 200 | 46.29 | 1.49 |
| 25.30 | 16.55 | 208 | 46.92 | 1.57 |
| 25.50 | 16.76 | 220 | 46.78 | 1.57 |
| 25.50 | 16.76 | 220 | 46.78 | 1.51 |
| 25.60 | 16.85 | 223 | 46.93 | 1.51 |
| 25.60 | 16.85 | 224 | 46.90 | 1.51 |
| 25.30 | 16.12 | 200 | 47.55 | 1.53 |
| 25.70 | 16.17 | 210 | 46.63 | 1.50 |
| 25.47 | 16.57 | 212 | 46.86 | 1.51 |

Mean from mean temperature and pressure, weight of 100 cubic inches $\left.\begin{array}{r}46.87\\46.86\end{array}\right\}$ mean 46.865, mean specific gravity 1.51.

When due allowance is made for water contained in alcohol of this specific gravity, 100 cubic inches will weigh 53.8 grains, temperature 60° and pressure 30 inches mercury, and when the deduction is made for the expansion of glass and mercury, it will give the weight for 100 cubic inches at 60° temperature and 30 inches pressure 46.30 grains, and specific gravity of the vapour 1.49, atmospheric air being 1. If we take a mean between Dr. Dalton's and Dr. Thomson's weight of hydrogen the vapour of pure alcohol will be 23.1 times hydrogen.

## Vapour of Ether.

The 42 inch tube was used in these experiments:—

| | | | |
|---|---|---|---|
| Capacity of the tube | 4.64 | cubic | inches, |
| ball | 3.46 | " | " |
| together | 8.1 | " | " |

Specific gravity of the ether .728. 1.8 grains in measure being equal to 1.31 grains in weight, were sent up.

*Twelve Experiments.*

| Length of the tube filled with vapour. | Pressure | Temperature | Wt. of 100 cub. inches of vapr. temp. 60° and pressure 30 in. | Spec. gravity of the vapour air = 1. |
|---|---|---|---|---|
| inches | inches | degrees | grains | |
| 19.77 | 9.27 | 125 | 82.53 | 2.66 |
| 20.10 | 9.50 | 132 | 83.00 | 2.67 |
| 20.75 | 10.15 | 170 | 82.00 | 2.64 |
| 21.00 | 10.20 | 185 | 80.47 | 2.59 |
| 21.37 | 10.50 | 204 | 82.54 | 2.66 |
| 21.50 | 11.14 | 240 | 81.92 | 2.64 |
| 21.75 | 10.95 | 230 | 81.66 | 2.63 |
| 21.50 | 10.80 | 220 | 81.23 | 2.62 |
| 21.50 | 10.80 | 215 | 81.38 | 2.62 |
| 21.50 | 10.72 | 210 | 81.36 | 2.62 |
| 21.60 | 10.92 | 212 | 80.00 | 2.58 |
| 21.75 | 10.97 | 230 | 81.55 | 2.63 |
| 21.17 | 10.50 | 198 | 81.63 | 2.63 |

When the deduction is made for expansion of glass and mercury, 100 cubic inches of the vapour at 60° and 30 inches pressure will weigh 79.46 grains, and its specific gravity will be 2.55, atmospheric air being 1.

## Vapour of Pyroxilic Spirit.

Tube 40 inches long and capacity 6.08 cubic inches, capacity of the ball 4.3 cubic inches, specific gravity of the spirit .810, two grains in

measure sent up the tube, being equal to 1.62 grains in weight.

*Twelve Experiments.*

| Length of the tube filled with vapour. | Pressure. | Temperature. | Wt. of 100 cubic in. at 60° temp. and 30 in pressure. | Spec. gr. of vapr. air = 1. |
|---|---|---|---|---|
| inches | inches | degrees | grains | |
| 28.25 | 18.19 | 250 | 41.70 | 1.30 |
| 27.75 | 17.45 | 230 | 43.70 | 1.40 |
| 27.70 | 18.60 | 220 | 50.35 | 1.30 |
| 27.50 | 18.62 | 210 | 40.00 | 1.28 |
| 27.60 | 18.62 | 212 | 39.91 | 1.28 |
| 28.00 | 19.02 | 230 | 39.86 | 1.28 |
| 28.15 | 19.15 | 235 | 40.34 | 1.30 |
| 28.25 | 19.25 | 238 | 39.69 | 1.28 |
| 28.50 | 19.54 | 254 | 39.40 | 1.27 |
| 28.75 | 19.79 | 266 | 40.96 | 1.32 |
| 28.37 | 19.43 | 254 | 40.12 | 1.29 |
| 27.70 | 18.70 | 215 | 40.00 | 1.30 |
| 28.04 | 18.82 | 234 | 40.55 | 1.30 |

When a deduction is made for expansion of mercury and glass, 100 cubic inches will be 39.53, and the specific gravity of the vapour will be 1.27, air being 1.

## Vapour of Acetic Acid.

I was favoured by Dr. Henry with a portion of the strongest and purest acid (crystallized at 54°

Fah.) he had in his possession. Its acidity was such that 5 ounces apothecaries' weight of lime water required 7 water grain measures of it in order to be made neutral. The same quantity of that lime water required 26½ grains, by measure of dilute sulphuric acid of 1.134 specific gravity. The 42 inch tube was used.

*Twelve Experiments.*

| Length of the tube filled with vapour. | Pressure. | Temperature. | Wt. of 100 cub. inches of 60° temp. and 30 in. pressure. | Spec. gravity of the vapour air being 1. |
|---|---|---|---|---|
| inches. | inches. | degrees. | grains. | |
| 27.80 | 16.30 | 221 | 73.57 | 2.37 |
| 28.2 | 16.70 | 228 | 72,00 | 2.32 |
| 29.0 | 16.60 | 240 | 74.84 | 2.41 |
| 28.5 | 17.10 | 232 | 76.75 | 2.47 |
| 28.2 | 17.65 | 236 | 74.16 | 2.39 |
| 28.2 | 17.65 | 239 | 74.17 | 2.39 |
| 28.3 | 17.75 | 244 | 75.00 | 2.41 |
| 29.1 | 18.55 | 258 | 74.12 | 2.39 |
| 28.7 | 18.15 | 248 | 73.77 | 2.37 |
| 28.3 | 17.75 | 240 | 75.00 | 2.42 |
| 28.3 | 17.75 | 242 | 75.00 | 2.42 |
| 28.3 | 17.85 | 244 | 75.02 | 2.42 |
| 28.4 | 17.56 | 239.3 | 75.64 | 2.40 |

When the deduction is made for the expansion of glass and mercury, 1 00 cubic inches will weigh 74 grains, and the specific gravity will be 2.37, atmospheric air being 1.

It is satisfactory to me to find that my results on steam from water, and on the vapour of alcohol and ether agree very nearly with those of Gay Lussac, and this encourages the hope that those which I have obtained from pyroxilic spirit and acetic acid will be found to be near approximations to the truth. In many of the combustible gases and vapours it would seem the atomic volumes are much the same as those of hydrogen. If this should be found true, it may lead us in many cases, to learn the atomic constitutions of compound elastic fluids from knowing the specific gravities of such fluids.

# AN
# EXPERIMENTAL ENQUIRY
## INTO THE STRENGTH AND OTHER PROPERTIES OF CAST IRON
## FROM VARIOUS PARTS OF THE UNITED KINGDOM.

By Mr. WILLIAM FAIRBAIRN.

Read 7th of March, 1837.

The multifarious uses to which cast iron is applied, and the facility with which it can be moulded into almost every shape, render the investigation of its properties a subject of interest in a national as well as an individual point of view. Many experiments to ascertain its strength, elasticity, and other properties have therefore been made by authors, not only of our own, but other countries; as by Banks, Rondelet, Muschet, Bramah, Dunlop, Brown, Rennie, Tredgold, &c. besides the numerous experiments made at my works by my friend Mr. Hodgkinson.

None of those writers, however, with the ex-

ception of Tredgold, have, so far as I know, made any inquiries into the fluidity of the different sorts of cast irons; nor has much attention been paid to their comparative powers of application.

The following pages contain—1st., a laborious enquiry into the transverse strength of cast irons from various parts of the kingdom; and, 2ndly, an extended investigation into the less cultivated field of their relative values, as regards their adaptation to the arts.

In pursuing these experiments it was originally my intention to have investigated the question of mixtures, or the proportions necessary for the production of different sorts of castings. This subject is, however, of such importance, and requires so much time and labour, that I am induced to forego its consideration for the present, and confine myself exclusively to the objects above stated. In adverting to this matter, however, it may be proper to remark that the same admixture or compound of pig iron is not suited for every description of casting; a water wheel axle, or steam engine beam, for instance, requires a different mixture to the finer and sof-

ter preparations for light machinery. Cylinders, air pumps, and pistons of steam engines have also (in practice) their peculiar compounds; and it is important in all these operations to have confirmed data (the results of actual experiment) for directing the labours of the architect, engineer, and mechanic.

Tredgold in his essay on the strength of cast iron seems to have been aware of the deficiencies under which the labours of the iron founder have been conducted; he describes the properties of the iron* but gives no proportions for the mixtures; nor have we at the present time any guide beyond what is indicated by the appearance of the fracture. The amalgamation of the different metals, however important in practice, is generally left to chance; or at best to the

* Soft iron yields easily to the file, when the external crust is removed, and is slightly malleable in a cold state.

White cast iron is less subject to be destroyed by rusting than the grey kind, and it is less soluble in acids; therefore it may be usefully employed when hardness is necessary, and when its brittleness is not a defect; but it should not be chosen for purposes where strength is necessary.

White cast iron, in a recent fracture, has a white and radiated appearance, indicating a crystalline structure; it is very brittle and hard. Gray cast iron has a granulated fracture of a gray colour with some metallic lustre; it is much softer and tougher than the white cast iron.—Tredgold's Essay, p 7.

imperfect knowledge of the person who attends the furnace: on some future occasion I may, however, make this a distinct subject of enquiry.

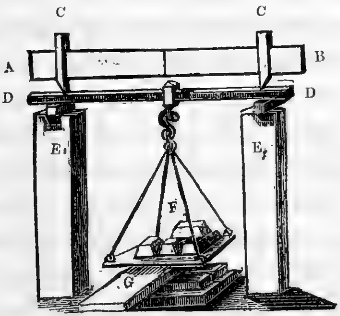
During the prosecution of the following experiments, I have been favoured with the assistance of Mr. Hodgkinson, to whom I am indebted for the calculations and many valuable suggestions; also to one of my own pupils, Mr. J. Patchett, who rendered valuable assistance.

Before exhibiting the experiments, I would here observe that they were made on quadrangular bars, one inch, and one inch and a half, square. These bars were loaded with weights suspended from the middle, and supported, first, on props 4 feet 6 in. asunder, and afterwards, their fractured halves, on supports 2 feet 3 in. asunder; the bars thus placed were loaded with weights, commencing, in the first series (4 feet 6 in.) with 14 lbs., and generally increasing in the ratio of that weight until the bar was broken.* This method was adopted in all the experiments, and conducted with such care as to ensure correct results.

*In the 2ft. 3in. bars, 28lbs. was not considered too great an increase.

The deflection was ascertained every time the weights were increased; and, in order to discover the defects of elasticity, the set was taken at equal intervals between the weights during the progress of the experiments. Considerable attention was also paid to observed discrepancies appertaining to the point at which the elasticity became defective.

The following sketch of the apparatus shows in what manner the experiments were conducted :—




A B represents a straight edge or parallel guage, having two dovetailed slides C C, to regulate the height above the bar D D, resting upon the supports E E, and F the scale on which the weights were laid. The

method adopted in removing the weights, for the purpose of ascertaining the defects of elasticity, was by pressing down the end of a wooden lever, G, applied to the bottom of the scale, and thus raising it to a height sufficient to disengage the hook every time the set was taken; this was done by a slow steady motion, and the weights were laid gently upon the scale to prevent jerks or sudden derangement of the parts under strain.

In 52 experiments on inch bars 4 ft. 6 in. between the supports, the deflections varied (with equal weights of 350 lbs.) from .707 to 1.582, which for the whole number gives a mean of 1.051 as follows:—

*Table of deflections as exhibited with equal weights on bars cast to be* 1*in. square* and* 4*ft.* 6*in. between the supports.*

| No. of Experiments. | Names. | Weight in lbs. | Deflection in inches. | Mean. |
|---|---|---|---|---|
| 1 | Apedale. | 350 | 1.115 | 1,106 |
| 2 | ,, | 350 | 1.098 | |
| 3 | Varteg. | 350 | 1.050 | 1,045 |
| 4 | ,, | 350 | 1.040 | |
| 5 | Monkland. | 350 | 1.352 | 1,358 |
| 6 | ,, | 350 | 1.365 | |
| 7 | Carroll. | 350 | 0.810 | 0,825 |
| 8 | ,, | 250 | 0.840 | |
| 9 | Windmill End. | 350 | 0.834 | 0,862 |
| 10 | ,, | 350 | 0.890 | |
| 11 | Low Moor. | 350 | 1.180 | 1,195 |
| 12 | ,, | 350 | 1.210 | |
| 13 | Butterley. | 350 | 1.130 | 1,142 |
| 14 | ,, | 350 | 1.155 | |
| 15 | Beaufort. | 350 | 0.745 | 0,726 |
| 16 | ,, | 350 | 0.707 | |
| 17 | Maesteg. | 350 | 1.115 | 1,144 |
| 18 | ,, | 350 | 1.176 | |
| 19 | Level. | 350 | 1.023 | 1,005 |
| 20 | ,, | 350 | 0.987 | |
| 21 | Old Park. | 350 | 1.025 | 1,021 |
| 22 | ,, | 350 | 1.016 | |
| 23 | Calder. | 350 | 1.240 | 1,218 |
| 24 | ,, | 350 | 1.197 | |
| 25 | Clyde. | 350 | 0.979 | 0,985 |
| 26 | ,, | 350 | 0.993 | |
| 27 | Eagle Foundry. | 350 | 1.083 | 1,047 |
| 28 | ,, | 350 | 1.012 | |
| 29 | Adelphi. | 350 | 1.177 | 1,125 |
| 30 | ,, | 350 | 1.073 | |
| 31 | Pontypool. | 350 | 1.073 | 1,088 |
| 32 | ,, | 350 | 1.104 | |
| 33 | Oldberry. | 350 | 0.973 | 1,008 |
| 34 | ,, | 350 | 1.043 | |
| 35 | Pentwyn. | 350 | 0.885 | 0,878 |
| 36 | ,, | 350 | 0.872 | |
| 37 | Gartsherrie. | 350 | 1.042 | 1,062 |
| 38 | ,, | 350 | 1.083 | |
| 39 | Dundayven. | 350 | 0.926 | 0,961 |
| 40 | ,, | 350 | 0.995 | |
| 41 | Lays Works. | 350 | 1.582 | 1,524 |
| 42 | ,, | 350 | 1.466 | |
| 43 | Bute. | 350 | 0.942 | 0,960 |
| 44 | ,, | 350 | 0.979 | |
| 45 | Brimbo. | 350 | 1.016 | 1,046 |
| 46 | ,, | 350 | 1.076 | |
| 47 | Ponkey. | 350 | 0.834 | 0,840 |
| 48 | ,, | 350 | 0.846 | |
| 49 | Frood. | 350 | 1.092 | 1,127 |
| 50 | ,, | 350 | 1.162 | |
| 51 | Lane End. | 350 | 1.005 | 1,022 |
| 52 | ,, | 350 | 1.039 | |

REMARK.—We have therefore a mean deflection of 1,051, rather more than 1 inch from the whole number of experiments.

* The bars usually measured somewhat more than 1 inch square, as will be seen from the experiments; the deflections therefore would have been a little greater than those shown above, if the bars had been exactly one inch square.

It appears from authors, who have recently written on the strength of materials, that all crystalline or tenacious bodies, subjected to a transverse strain, have one of their sides elongated, whilst the other is compressed; they are also agreed as to a point, called the neutral point, round which revolve the opposing forces of tension and compression. In our experiments it is evident, as the deflection increases, the atoms or crystals on the lower side of the bar must be separated, and those of the upper side brought nearer together.* Mr. Hodgkinson in his paper on the strength of iron beams, (Manchester Memoirs, vol. 5, second series, page 409,) states the following proposition.—'Suppose a beam horizontal, with one end firmly fixed in a wall, and a weight hung at the other, it will bend; but it is evident that could not take place, except by the lengthening of the top parts, by the compression of the bottom, or by both. Now both of these actually take place; and hence there is some intermediate point or line between the top and bottom of the beam, where the particles are neither extended or compressed. This line may properly be called the

* This has only lately been admitted, bodies have hitherto been considered incompressible.

neutral line." He then goes on to illustrate the theory by a diagram to show that the sum of the forces exerted by the extended fibres is equal to the sum of the forces exerted by the compressed ones, and thus concludes :—" Now it is evident that the extensions or compressions of any particles within these surfaces will be as their distances from the line A B (meaning the neutral line ;) and the forces exerted by those particles must be in the same proportion, so long as the elasticity remains perfect ; for then the forces are found to be as the extensions or compressions. Afterwards the forces of the particles would be as some different functions of their distances from the neutral line."

In further illustration of this subject, suppose we place a bar of cast iron upon the supports E E in the figure, and subject it to pressure, by weights suspended from the middle; it is obvious, in this case, that the resisting forces of extension and compression immediately come into operation ; the particles forming the convex side of the bar, become more widely separated, whilst those on the concave are more closely condensed. It is evident, therefore, that a change of position must take place in

the granulated state of the bar, in order to resist the forces thus operating to produce rupture, either by compression above, or forcible extention below.

From this view of the case, a question arose as to the actual state of the atoms under different degrees of pressure; it appeared to me that the tensible and compressed forces would at every change produce a new adjustment of the parts, and either afford evidence of their adaptation to the load, or demonstrate a progressive yielding to a force sufficient ultimately to destroy the resistance.

On consulting the works of different authors, I found them nearly agreed in supposing that materials could be loaded to one-third or more of the breaking weight, without injuring their elasticity. In pursuing these experiments I was however led to a different conclusion, by observed discrepancies in the bars, accompanied by much earlier indications of impaired elasticity. I mentioned this circumstance to Mr. Hodgkinson, and found similar results had been obtained by him, in experiments made for the British Association previous to those now in progress.

So striking a coincidence, induced a new and extended series of experiments, to determine whether the elasticity is not generally injured with much less than one-third of the breaking weight, and the annexed tables show this to be the case: some slight injury with very small weights is certainly produced; but it admits of doubt whether or not it affects the ultimate strength of the bar,—at first sight it appeared that a weight sufficient to produce a permanent set would, if continued, be sufficient to break the bar, and that time alone was necessary to effect the rupture.

Mr. Hodgkinson took a different view of the case, and conceived that bodies by virtue of their elasticity, combined with slight ductility, might adjust themselves so as permanently to bear a load, nearly sufficient to break them at once. He had formed this view from having found that in experiments on wrought iron wires, torn asunder many times in succession, they bore nearly as much the last time as the first.—See Manchester Memoirs, Vol. 5.

A phenomenon so curious and interesting led to the enquiry. How much will cast iron per-

manently bear without endangering its security? This was an exceedingly important question, which in order to solve, we came to the conclusion of putting to the test of experiment.

For this purpose ten bars were procured, each cast to be one inch square, and having loaded them with different weights,—some nearly approaching the breaking point,—and supported their ends on props 4 ft. 6in. asunder,—they were left in this position to determine how long they would support the loads without breaking. Five weeks have now elapsed since they were charged, and, from what we can at present observe, there is every appearance of a long and tedious experiment.* I should here mention that the deflections are taken weekly, in order to determine the alterations in the state of the bars.

* Since the above was written, one of the bars has given way and broken near the centre, after having sustained a load of 448 lbs. for 37 days. The deflection was observed to have increased from 1.904 to 2.014 between the time of loading and that of the last measurement, three days before the rupture took place. It must be observed that this bar was thinner than any of the others now tried, and had borne for this period a weight larger than had broken bars of the same size in previous experiments upon this iron, when the weights were laid on without loss of time. All the other bars continue to sustain their loads, though they have born them for many months; the deflections however are slightly on the increase. The particulars of these will be given in the Seventh Report of the British Association for the Advancement of Science.

The following being a practical enquiry, it is not necessary to step out of the way in search of general principles: the effort will therefore be confined simply to investigating the peculiar merits of the different irons of British manufacture; exhibiting their most remarkable features, and rendering their applicability matter of certainty as respects strength, fluidity, power of being worked, &c. The enquiry will, therefore, in a great measure be devoted to those objects; shewing the strength and deflection of each iron under a transverse strain in the first instance, and subsequently interspersed with observations arising from microscopic examination, and the turning and filing process to which they were severally subjected.

In the annexed tables I have given an abridged form of the experiments, and selected such weights, deflections, and numbers, as will give a succinct and clear illustration of the methods adopted in the experiments.—To each class of experiments, and to each iron, is attached a tabular form of results, with the values reduced to those of bars exactly one inch square; the reductions being made by supposing, as is generally admitted, that the strength of rectangular

beams is as the breadth multiplied by the square of the depth; the length being given: and that the ultimate deflection is inversely as the depth. The power of resisting impact in each iron is reckoned by the product of the breaking weight multiplied by the ultimate deflection: depending upon the supposition that the elasticity remains unimpaired; and that the blow, in all cases, where the results are to be compared together, is given with the same striking body or hammer upon beams all of which are equal in weight. These suppositions, however, are not strictly true, but as the beams are all very nearly of equal weight, the product above mentioned will give a comparative measure near enough for practical purposes; as may be inferred from the paper on impact upon beams—Fifth Report of the British Association for the Advancement of Science.—The modulus of elasticity is given in pounds for a base of a square inch; this weight may be taken as the measure of the stiffness of the iron. It was usually calculated from the deflection caused by 112lbs. on the 4ft. 6in. bars.

## No. I.

## ENGLISH IRONS.

Apedale, No. II, Pig Iron, Hot Blast, Newcastle, Staffordshire.

| Experiment 1st. Depth of Bar..........1.010 Breadth do..........1.015 Distance between supports.........4ft. 6in | | | Experiment 2nd. Depth of Bar.......1.025 Breadth do..........1·002 Distance between supports..........4ft. 6in. Weight of Bar 5ft. long, 15lbs. 3oz. | | | Experiment 3rd. Depth of Bar......1.015 Breadth do.......1.015 Distance between supports........2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 112 | .275 | .008 | 112 | .280 | .010 | 112 | .034 | — |
| 182 | .485 | .019 | 182 | .490 | .028 | 224 | .072 | .003 |
| 238 | .674 | .040 | 238 | .672 | .051 | 336 | .112 | .005 |
| 294 | .882 | .068 | 294 | .874 | .084 | 448 | .155 | .007 |
| 350 | 1.115 | .110 | 350 | 1.098 | .110 | 560 | .204 | .013 |
| 378 | 1.242 | .138 | 406 | 1.340 | .159 | 672 | .255 | .020 |
| 406 | 1.372 | .165 | 462 | 1.613 | .227 | 784 | .305 | .029 |
| 434 | broke | | 476 | 1.700 | broke | 896 | .370 | .040 |
| | | | | | | 952 | broke | |
| This bar was unsound at the bottom side, and broke $7\frac{1}{2}$ inches from the centre. | | | Broke one inch from the centre. | | | ∴ Ultimate deflection = .399. Broke at the centre. | | |

| Results reduced to those of Bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, ($b$.) | Ultimate deflection, ($d$.) | Product $b \times d$ or power of resisting impact. |
| Exp. 2nd, bar 4ft. 6in.......... | 7.017 | 14852000 | 457 | 1.730 | 790.6 |
| Exp. 3rd, bar 2ft. 3in.......... | | | 910.4 | .405 | 368.7 |

This Iron presents a clear and rather open fracture; when viewed with a magnifier, the crystals appear porous in the centre, but smaller and more compact as they approach the outer edge.

Appearance light grey, slightly tinged with blue.—It is a free working iron, rather stiff in its texture, but yields moderately to the chisel and file. I should conceive it useful in combination with metals of greater fluidity.

## No. II.
## ENGLISH IRON.
### Adelphi, No. 2, Pig Iron, Cold Blast, Derbyshire.

| *Experiment 1st.*<br>Depth of Bar......1.530<br>Breadth do........1.470<br>Distance between supports......4ft. 6in.<br>Weight of bar 5ft. long, 34lbs. 3oz. | | | *Expdriment 2nd.*<br>Depth of bar...... 1.006<br>Breadth do....... .990<br>Distance between supports ....4ft. 6in,<br>Weight of bar 5ft. long. 15lbs. 7oz. | | | *Experiment 3rd.*<br>Depth of bar.......1,055<br>Breadth do........ .995<br>Distance between supports.....4ft. 6in.<br>Weight of bar 5ft. long, 15lb. 9oz. | | | *Experiment 4th.*<br>Depth of bar....1.015<br>Breadth do......1.004<br>Distance between supports ....2ft. 3in. | | | *Experiment 5th.*<br>Depth of bar ....1.038<br>Breadth do.......1.002<br>Distance between supports....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, load removed | Weight in lbs. | Deflection in inches. | Deflection, Load removed, | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 56 | .028 | + | 56 | .140 | + | 30 | .065 | + | 112 | .034 | + | 112 | .034 | + |
| 112 | .058 | .003 | 112 | .307 | .012 | 56 | .130 | .003 | 224 | .073 | .004 | 224 | .072 | .003 |
| 224 | .120 | .006 | 168 | .490 | .033 | 112 | .282 | .016 | 336 | .115 | .007 | 336 | .111 | .005 |
| 836 | .188 | .014 | 224 | .690 | .062 | 168 | .450 | .035 | 448 | .161 | .011 | 448 | .156 | .009 |
| 443 | .265 | .023 | 280 | .906 | .100 | 224 | .627 | .058 | 560 | .212 | .019 | 560 | .206 | .014 |
| 560 | .344 | .035 | 336 | 1.130 | .149 | 280 | .825 | .087 | 672 | .270 | .028 | 672 | .260 | .023 |
| 672 | .427 | .047 | 392 | 1.405 | .218 | 336 | 1.030 | .128 | 784 | .332 | .041 | 784 | .320 | .035 |
| 784 | .526 | .067 | 420 | 1.560 | | 392 | 1.265 | .185 | 896 | .405 | .060 | 896 | .392 | .054 |
| 896 | .610 | .084 | 434 | broke | | 448 | 1.525 | .262 | 952 | broke | | 952 | .432 | |
| 1008 | .719 | .110 | | | | 476 | 1.670 | | | | | 980 | broke | |
| 1120 | .830 | .140 | | | | 497 | broke | | | | | | | |
| 1232 | .951 | .177 | | | | | | | | | | | | |
| 1344 | 1.080 | .226 | | | | | | | | | | | | |
| 1400 | 1.161 | broke | | | | | | | | | | | | |
| Broke at the centre. | | | ∴ Ultimate deflection =1.632.<br>Broke ⅕ of an inch from the centre.—The elasticity seemed to be injured with 30lbs or less. | | | ∴ Ultimate deflection = 1.779.<br>Broke ¼ of an inch from the centre. | | | ∴ Ultimate deflection = .439.—Broke ⅜ of an inch from the centre. 672lbs remained on 42 hours, when the deflection increased from .270 to .277; the defect of elasticity from .028 to .034. | | | ∴ Ultimate deflection = .451.<br>Broke at the centre. | | |

In Experiment 4th the bar, as mentioned above, sustained $\frac{2}{3}$ of the load for forty-two hours; at the close of the experiment (when the load was removed) an increase of deflection and defect of elasticity had taken place, but probably not more than might have been expected from the particles adjusting themselves to the load.

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | | | 406.9 | 1.776 | 722.7 |
| Experiment 2nd, bar 4ft. 6in. between supports | 7.080 | 14249000 | 433.2 | 1.642 | 711.3 |
| Experiment 3rd, bar 4ft. 6in. between supports | 7.080 | 13382000 | 448.8 | 1.877 | 842.4 |
| Mean | 7.080 | 13815500 | 441.0 | 1.759 | 776.8 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 920.4 | .446 | 410.5 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 907.6 | .468 | 424.7 |
| Mean | | | 914.0 | .457 | 417.6 |

## No. III.

## ENGLISH IRONS.

Butterley, —, Pig Iron, ——, Derbyshire.

| *Experiment 1st.* | | | *Experiment 2nd.* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar...... 1.000<br>Breadth do........ .989<br>Distance between supports ..... 4ft. 6in.<br>Weight of Bar 5ft. long, 14lb. 13oz. | | | Depth of Bar...... .991<br>Breadth do ....... .988<br>Distance between Supports.... 4ft. 6in.<br>Weight of Bar 5ft. long, 14¾lbs | | | Depth of Bar...... 1.015<br>Breadth do ....... .993<br>Distance between supports ..... 2ft. 3in. | | | Depth of Bar.... 1.014<br>Breadth do ...... .988<br>Distance between supports .... 2ft. 3in. | | |
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .067 | .000 | 28 | .070 | .000 | 112 | .033 | — | 112 | .034 | — |
| 56 | .130 | .002 | 56 | .140 | .002 | 224 | .070 | + | 224 | .073 | + |
| 126 | .331 | .015 | 126 | .339 | .016 | 336 | .108 | .003 | 336 | .115 | .004 |
| + | + | + | 182 | .515 | .037 | 448 | .151 | .006 | 448 | .160 | .007 |
| 182 | .504 | .040 | 238 | .710 | .063 | 560 | .195 | .009 | 560 | .210 | .011 |
| + | + | + | + | + | + | 672 | .246 | .015 | 672 | .263 | .018 |
| 238 | .695 | .065 | 294 | .921 | .099 | 784 | .300 | .026 | 784 | .320 | .026 |
| 294 | .903 | .100 | 350 | 1.155 | .147 | 896 | .362 | .038 | 896 | .390 | .043 |
| 350 | 1.130 | .147 | 406 | 1.420 | .203 | 1008 | .442 | .064 | 1008 | broke | broke |
| 406 | 1.385 | .203 | 434 | 1.580 | .253 | 1092 | broke | broke | | | |
| 462 | 1.685 | .295 | 462 | broke | broke | | | | | | |
| 490 | 1.855 | .340 | | | | | | | | | |
| 497 | broke | broke | | | | | | | | | |
| ∴ Ultimate deflection =1,895.<br>Broke one inch from the centre. | | | ∴ Ultimate deflection =1.752.<br>Broke ⅜ of an inch from the centre. 434lbs. were hung from the bar for 14 hours, when the deflection was found to be 1.630, and the defect of elasticity .292. | | | ∴ Ultimate deflection =.493.<br>Broke ⅜ of an inch from the centre. | | | ∴ Ultimate deflection =.470.<br>Broke in the centre | | |

| Results reduced to those of bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
| Experiment 1st., bar 4ft. 6in. between supports............. | | 15372000 | 502.5 | 1.895 | 952.3 |
| Experiment 2nd., bar 4ft. 6in. between supports............. | 7.038 | 15387000 | 476.2 | 1.736 | 826.7 |
| Mean.................................. | | | 489.3 | 1.815 | 889.5 |
| Experiment 3rd., bar 2ft. 3in. between supports............. | | | 1068 | .500 | 534.0 |
| Experiment 4th., bar 2ft. 3in. between supports............. | | | 992.3 | .477 | 473.3 |
| Mean.................................. | | | 1030.1 | .488 | 503.6 |

The general appearance of the fracture is a dark grey, with smaller crystals than in either the Adelphi or Apedale. Its fluidity is much akin to the Low Moor iron; it works freely under the file, and is well suited for almost every description of casting.—The power of resisting impact in these specimens is even greater than in the Low Moor.

We have no description of the manufacture of the Butterley iron, but I strongly suspect it is No. 2, made from the hot blast.

## No. IV.

## ENGLISH IRON.

Eagle Foundry, No. 2, Pig Iron, Hot Blast, Staffordshire.

| *Experiment 1st.* | | | *Experiment 2nd.* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar...... 1.025<br>Breadth do........ 1.025<br>Distance between supports..... 4ft. 6in.<br>Weight of Bar 5ft. long, 15lb. 11oz. | | | Depth of Bar...... 1.024<br>Breadth do ....... 1.045<br>Distance between Supports..... 4ft. 6in.<br>Weight of Bar 5ft. long, 16lbs | | | Depth of Bar...... 1.015<br>Breadth do ....... 1.024<br>Distance between supports..... 2ft. 3in. | | | Depth of Bar.... 1.041<br>Breadth do...... 1.025<br>Distance between supports .... 2ft. 3in. | | |
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 56 | .141 | .003 | 14 | .032 | + | 112 | .034 | + | 112 | .030 | + |
| 112 | .288 | .012 | 56 | .132 | .003 | 224 | .072 | .004 | 224 | .063 | .002 |
| 168 | .453 | .029 | 112 | .270 | .015 | 336 | .113 | .006 | 336 | .097 | .004 |
| 224 | .633 | .050 | 168 | .429 | .031 | 448 | .155 | .010 | 448 | .135 | .007 |
| 280 | .826 | .078 | 224 | .600 | .053 | 560 | .201 | .014 | 560 | .174 | .010 |
| 336 | 1.040 | .115 | 280 | .780 | .079 | 672 | .249 | .020 | 672 | .216 | .013 |
| 392 | 1.268 | .162 | 336 | .972 | .111 | 784 | .304 | .030 | 784 | .264 | .020 |
| 420 | 1.398 | | 392 | 1.182 | .156 | 896 | .369 | .041 | 896 | .317 | .030 |
| 448 | broke | | 420 | 1.296 | | 924 | broke | | 1008 | .379 | .045 |
| | | | 448 | broke | | | | | | | |
| ∴ Ultimate deflection =1.520.<br>Broke ¾ of inch from the centre. | | | ∴ Ultimate deflection =1.404.<br>Broke one inch from the centre. | | | ∴ Ultimate deflection =.384.<br>Broke ¾ of an inch from the centre, | | | Broke ½ an inch from the centre when the weight 1008 was re-placed. | | |

| Results reduced to those of bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
| Experiment 1st, bar 4ft. 6in between supports............. | 6.997 | 13869000 | 416 | 1.558 | 648.1 |
| Experiment 2nd, bar 4ft. 6in. between supports............. | 7.080 | 14553000 | 400.6 | 1.467 | 587.7 |
| Mean.............................. | 7.038 | 14211000 | 408.3 | 1.512 | 617.9 |
| Experiment 3rd, bar 2ft. 3in. between supports............. | | | 875.9 | .389 | 340.7 |
| Experiment 4th, bar 2ft. 3in. between supports............. | | | 907.5 | .395 | 358.4 |
| Mean.............................. | | | 891.7 | .392 | 349.5 |

The Eagle Foundry Iron has an uniform and rather porous fracture, with a deeper blue colour than either the Butterley or the Apedale.—It is similar in appearance to the Coed-Talon, Hot Blast; and from the ease with which it cuts, I should conceive it well adapted to the finer descriptions of castings. The crystals appear more regular than in any of the former irons examined.

## No. V.
## ENGLISH IRONS.
### Level, No. 1, Pig Iron, Hot Blast, Staffordshire.

| *Experiment 1st.* Depth of Bar......1.013 Breadth do.........1,005 Distance between supports......4ft. 6in. Weight of bar 5ft. long, 15lbs. 1oz. | | | *Experiment 2nd.* Depth of bar...... 1.009 Breadth do....... 1.015 Distance between supports .... 4ft. 6in, Weight of bar 5ft. long. 15lbs. 12oz. | | | *Experiment 3rd.* Depth of bar.......1,500 Breadth do........1.470 Distance between supports.....4ft. 6in. Weight of bar 5ft. long, 34lb. 0oz. | | | *Experiment 4th.* Depth of bar.... 1.025 Breadth do...... 1.000 Distance between supports .... 2ft. 3in. | | | *Experiment 5th.* Depth of bar .... 1.040 Breadth do......1.024 Distance between supports ....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed, | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 56 | .139 | + | 56 | .135 | + | 112 | .060 | .005 | 112 | .032 | — | 112 | .031 | — |
| 112 | .279 | .015 | 112 | .268 | .009 | 224 | .120 | .010 | 224 | .067 | — | 224 | .064 | — |
| 168 | .440 | .031 | 168 | .418 | .020 | 336 | .183 | .017 | 336 | .104 | + | 336 | .100 | + |
| 224 | .610 | .050 | 224 | .586 | .039 | 448 | .250 | .026 | 448 | .144 | .007 | 448 | .137 | .007 |
| 280 | .790 | .078 | 280 | .762 | .062 | 560 | .322 | .036 | 560 | .189 | .010 | 560 | .177 | .010 |
| 336 | .982 | .105 | 336 | .948 | .090 | 672 | .397 | .049 | 672 | .236 | .013 | 672 | .222 | .014 |
| 392 | 1.192 | .142 | 392 | 1.151 | .124 | 784 | .478 | .057 | 784 | .285 | .020 | 784 | broke | |
| 448 | 1.415 | .193 | 448 | 1.370 | .178 | 896 | .553 | .071 | 896 | .341 | .034 | | | |
| 476 | broke | | 476 | broke | | 1008 | .641 | .085 | 952 | broke | | | | |
| | | | | | | 1120 | .735 | .112 | | | | | | |
| | | | | | | 1232 | .840 | .137 | | | | | | |
| | | | | | | 1344 | .937 | .159 | | | | | | |
| | | | | | | 1400 | broke | | | | | | | |
| ∴ Ultimate deflection =1.525. Broke at the centre. | | | ∴ Ultimate deflection =1.474. Broke at the centre. | | | ∴ Ultimate deflection =.990, and 1429lbs breaking weight if the bar had been 1.50 square | | | ∴ Ultimate deflection =.368. Broke at the centre. | | | ∴ Ultimate deflection =.267. Broke ½ an inch from the centre. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection, (*d.*) | Productr $b \times d$ o power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ............ | 7.101 | 15127000 | 461.6 | 1.545 | 713.2 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.059 | 15778000 | 460.6 | 1.487 | 685.0 |
| Mean ................................ | 7.080 | 15452500 | 461.1 | 1.516 | 699.1 |
| Experiment 3rd., bar 4ft. 6in. between supports............ | | | 423.3 | 1.207 | 510.9 |
| Experiment 4th., bar 2ft. 3in. between supports............ | | | 906.1 | .377 | 341.6 |
| Experiment 5th., bar 2ft. 3in. between supports............ | | | 707.8 | .278 | 196.7 |
| Mean................................ | | | 806.9 | .327 | 269.1 |

## No. VI.
## ENGLISH IRON.
### Level, No. 2, Pig Iron, Hot Blast, Staffordshire.

| *Experiment 1st.* | | | *Experiment 2nd.* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | | *Experiment 5th.* | | | *Experiment 6th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar......1.040 Breadth do....... 1.024 Distance between supports......4ft. 6in. Weight of Bar 5ft. long, 16lbs. 4oz. | | | Depth of Bar...... 1.030 Breadth do........1.010 Distance between supports..... 4ft. 6in. Weight of Bar 5ft. long, 15lb. 10oz. | | | Depth of Bar......1.030 Breadth do......1.000 Distance between Supports......4ft. 6in. Weight of Bar 5ft. long, 15lbs. 10oz. | | | Depth of Bar.....1.058 Breadth do ......1.024 Distance between supports .... 2ft. 3in. | | | Depth of Bar.... 1.022 Breadth do......1.029 Distance between supports .... 2ft. 3in. | | | Depth of bar.... Breadth do...... Distance between supports .... | | |
| Weight in lbs. | Deflection in inches. | Deflection, load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 56 | .120 | .002 | 56 | .136 | .002 | 56 | .130 | .003 | 112 | .026 | — | 112 | .030 | | 112 | .032 | |
| 112 | .242 | .009 | 112 | .226 | .010 | 112 | .270 | .015 | 224 | .055 | + | 224 | .066 | | 224 | .068 | |
| 168 | .382 | .019 | 168 | .412 | .021 | 168 | .417 | .027 | 336 | .086 | + | 336 | .105 | | 336 | .104 | |
| 224 | .527 | .031 | 224 | .573 | .041 | 224 | .578 | .043 | 448 | .119 | .005 | 448 | .143 | | 448 | .144 | |
| 280 | .685 | .052 | 280 | .742 | .065 | 280 | .750 | .066 | 560 | .154 | .008 | 560 | .185 | | 560 | .187 | |
| 336 | .858 | .080 | 336 | .930 | .090 | 336 | .927 | .093 | 672 | .190 | .010 | 672 | .233 | | 672 | .231 | |
| 392 | 1.033 | .106 | 392 | 1.128 | .129 | 392 | 1.124 | .127 | 784 | .230 | .014 | 784 | .277 | | 784 | .274 | |
| 448 | 1.230 | .149 | 420 | 1.233 | | 420 | broke | | 896 | .271 | .020 | 896 | .332 | | 896 | .324 | |
| 476 | 1.333 | | 448 | broke | | | | | 1008 | .318 | .029 | 1008 | .391 | | 952 | broke | |
| 490 | broke | | | | | | | | | | | 1036 | broke | | | | |
| ∴ Ultimate deflection =1.384. Broke $\frac{7}{8}$ of an inch from the centre. | | | ∴ Ultimate deflection =1.337. Broke $\frac{3}{4}$ of an inch from the centre. | | | ∴ Ultimate deflection =1.222. Broke at the centre. | | | Broke with the 1008 laid on again, $\frac{5}{8}$ of an inch from the centre. | | | | | | This bar had borne within 28lbs. of the breaking weight. | | |

Experiment 5th and 6th were made by Mr. Hodgkinson. In the former the bar was cut in the middle to half its depth from the top with a saw, and the cut filled up with soft steel. In the latter or Experiment 6th, the bar was cut in the middle two-thirds through from the top downwards, and the aperture filled up with steel as before.

The dimensions of the last bar were not taken, but as all the bars were cast from the same model, and comparing the breaking weight in Experiment 5th and 6th with that in Experiment 4th, or with twice the breaking weights of the bars of double length in Experiment 1, 2 and 3, we shall see that the bar cut through half of its depth, and the cut filled up as above, bore more than the rest, and that the bar cut through two-thirds of its depth and filled in the same manner, bore nearly, if not quite, as much as the whole ones.

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, ($b.$) | Ultimate deflection ($d.$) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | 6.997 | 15817000 | 442.4 | 1.439 | 636.6 |
| Experiment 2nd., bar 4ft. 6in. between supports | 7.059 | 14962000 | 418.1 | 1.377 | 575.8 |
| Experiment 3rd., bar 4ft. 6in. between supports | 7.038 | 14944000 | 395.9 | 1.259 | 498.4 |
| Mean | 7.031 | 15241000 | 418.8 | 1.358 | 570.2 |
| Experiment 4th., bar 2ft. 3in. between supports | | | 879.4 | .336 | 295.5 |

There is something anomalous in the Level Iron, and that more particularly as respects the manufacture; it has generally been supposed to contain an admixture of cinder; but comparing the results of these experiments with others, the strength does not appear to be much reduced.—The cooling or shrinking of this iron is rather remarkable, the contraction is not only greater than in most others, but when cast in moulds, the castings appear collapsed on all sides with deep indentations, as if the crystals had been forced inwards during the process of cooling.

From irregularities indicated in these experiments, I was induced to extend them to a greater length than at first intended; this was done principally for the purpose of investigating the shrinkage and other properties peculiar to this iron.

The Level gave better results than was at first anticipated; it sustains with considerable tenacity a heavy load, but indicates weakness in its power of resisting impact, and is irregular in its strength, as shown in the experiments on the short specimens. The fracture presents a dull grey colour, closely granulated, but less ductile in appearance than either the Apedale or Adelphi.—It is certainly inferior to the Butterley and Eagle Foundry specimens—cuts short and crumbles under the file.

## No. VII.

## ENGLISH IRONS.

### Low Moor, No. 2, Pig Iron, Cold Blast, Yorkshire.

| *Experiment 1st.* Depth of Bar......1.004 Breadth do.........1.004 Distance between supports......4ft. 6in. Weight of bar 5ft. long, 14lbs. 14oz. | | | *Experiment 2nd.* Depth of bar....... .995 Breadth do.......1.015 Distance between supports .....4ft. 6in, Weight of bar 5ft. long. 14lbs. 12oz. | | | *Experiment 3rd.* Depth of bar.......1.004 Breadth do.........1.004 Distance between supports .....2ft. 3in. | | | *Experiment 4th.* Depth of bar.... 1.005 Breadth do.......1.005 Distance between supports....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed, | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 56 | .143 | .005 | 56 | .147 | .007 | 112 | .032 | — | 112 | .036 | — |
| 112 | .298 | .007 | 112 | .305 | .019 | 224 | .073 | + | 224 | .078 | + |
| 182 | .518 | .043 | 182 | .531 | .050 | 336 | .115 | .005 | 336 | .120 | .005 |
| 238 | .713 | .070 | 238 | .735 | .079 | 448 | .163 | .008 | 448 | .166 | .008 |
| 294 | .938 | .107 | 294 | .955 | .115 | 560 | .213 | .013 | 560 | .220 | .011 |
| 350 | 1.180 | .156 | 350 | 1.210 | .170 | 672 | .265 | .020 | 672 | .278 | .021 |
| 406 | 1.461 | .230 | 406 | 1.500 | .244 | 784 | .327 | .031 | 784 | .341 | .032 |
| 462 | 1.803 | .335 | 448 | 1.764 | | 896 | .400 | .048 | 896 | .412 | .050 |
| 469 | broke | | 462 | broke | | 952 | broke | | 952 | .457 | |
| | | | | | | | | | 1008 | .506 | broke |
| ∴ Ultimate deflection = 1.844. Broke $\frac{1}{2}$ of an inch from the centre, | | | ∴ Ultimate deflection = 1.863. Broke $\frac{5}{8}$ an inch from the centre. | | | ∴ Ultimate deflection = .434. Broke $\frac{1}{4}$ of an inch from the centre. | | | Broke with 1008lbs. $\frac{1}{2}$ an inch from the centre. | | |

| Results reduced to those of Bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, (*b*.) | Ultimate deflection, (*d*.) | Product *b* x *d* or power of resisting impact. |
| Experiment 1st., bar 4ft. 6in. between supports............ | 7.026<br>7.059 | 14561000 | 463.4 | 1.8·1 | 858.0 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.080 | 14458000 | 459.8 | 1.854 | 852.[illegible] |
| Mean.............................. | 7.055 | 14509500 | 461.6 | 1.852 | 855.2 |
| Experiment 4th., bar 2ft. 3in. between supports............ | | | 940.7 | .436 | 409.9 |
| Experiment 5th., bar 2ft. 3in. between supports............ | | | 993.0 | .509 | 505.5 |
| Mean.............................. | | | 966.8 | .472 | 457.6 |

The Low Moor indicates less brilliancy in the crystals than the Apedale;—colour a deep grey, accompanied with fluidity and richness in the appearance of the fracture.—Its freedom of working is of the first order; it cuts easily with the chisel, and is peculiarly adhesive when reduced by the file.—This iron runs the thinner moulds without risk, and retains its fluidity much longer than most other metals.

## No. VIII.

## ENGLISH IRONS.

### Milton, No. 1, Pig Iron, Hot Blast, Yorkshire.

| *Experiment 1st.*<br>Depth of Bar......1.064<br>Breadth do..........1.064<br>Distance between supports......4ft. 6in.<br>Weight of bar 5ft. long, 16lbs· 9oz. | | | *Experiment 2nd.*<br>Depth of bar...... 1.058<br>Breadth do....... 1.020<br>Distance between supports .... 4ft. 6in,<br>Weight of bar 5ft. loug, 16lbs. 8oz. | | | *Experiment 3rd.*<br>Depth of bar ......1,090<br>Breadth do........1.047<br>Distance between supports .....2ft. 3in. | | | *Experiment 4th.*<br>Depth of bar.... 1.067<br>Breadth do......1.040<br>Distance between supports....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed, | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 42 | 1.03 | + | 42 | .103 | + | 112 | .033 | — | 112 | .033 | — |
| 112 | .294 | .010 | 112 | .298 | .006 | 224 | .066 | + | 224 | .070 | + |
| 182 | .499 | .038 | 182 | .518 | .033 | 336 | .103 | .004 | 336 | .110 | .004 |
| 238 | .685 | .065 | 238 | .710 | .056 | 448 | .143 | .007 | 448 | .153 | .006 |
| 294 | .892 | .094 | 294 | .922 | .090 | 560 | .186 | .009 | 560 | .200 | .009 |
| 350 | 1.126 | .139 | 350 | 1.160 | .135 | 672 | .236 | .015 | 672 | .250 | .016 |
| 406 | 1.382 | broke | 406 | 1.430 | .209 | 784 | .286 | .024 | 784 | .306 | .025 |
| | | | 420 | broke | | 896 | .350 | .038 | 896 | .372 | .041 |
| | | | | | | 952 | broke | | 924 | broke | |
| Broke ⅜ of an inch from the centre· | | | ∴ Ultimate deflection = 1.492.<br>Broke 1¼ inch from the centre. | | | ∴ Ultimate deflection = .379.<br>Broke at the centre. | | | ∴ Ultimate deflection = .388.<br>Broke ¼ inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ........ | 7.016<br>6.977 | 11701000 | 337.1 | 1.471 | 495.8 |
| Experiment 2nd., bar 4ft. 6in. between supports........ | 6.936 | 12248000 | 367.9 | 1.579 | 580.9 |
| Mean .................... | 6.976 | 11974500 | 352.5 | 1.525 | 538.3 |
| Experiment 3rd., bar 2ft. 3in. between supports ........ | | | 765.3 | .413 | 316.0 |
| Experiment 4th., bar 2ft. 3in. between supports ........ | | | 780.4 | .414 | 323.0 |
| Mean.................... | | | 772.8 | .413 | 319.5 |

## No. IX.
## ENGLISH IRON.
### Milton, No. 3, Pig Iron, Hot Blast, Yorkshire.

| *Experiment 1st.* Depth of Bar……1.010 Breadth do……. 1.014 Distance between supports……4ft. 6in Weight of Bar 5ft. long, 15¾lbs. | | | *Experiment 2nd.* Depth of Bar…… 1.036 Breadth do……….1.005 Distance between supports ….. 4ft. 6in. Weight of Bar 5ft. long, 16lbs. | | | *Experiment 3rd.* Depth of Bar……1.037 Breadth do ……..1.018 Distance between Supports……2ft. 3in | | | *Experiment 4th.* Depth of Bar…..1.050 Breadth do ……1.015 Distance between supports …. 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 42 | .093 | + | 42 | .092 | + | 112 | .028 | — | 112 | .027 | — |
| 56 | .126 | + | 56 | .128 | + | 224 | .060 | — | 224 | .057 | — |
| 126 | .300 | .008 | 126 | .288 | .014 | 336 | .093 | + | 336 | .090 | + |
| 182 | .453 | .027 | 182 | .431 | .029 | 448 | .129 | + | 448 | .125 | + |
| 238 | .617 | .045 | 238 | .582 | .045 | 560 | .165 | .004 | 560 | .160 | .005 |
| 294 | .796 | .070 | 294 | .749 | .066 | 672 | .209 | .007 | 672 | .200 | .007 |
| 350 | .983 | .100 | 350 | .927 | .095 | 784 | .252 | .013 | 784 | .240 | .013 |
| 406 | 1.193 | .143 | 406 | 1.120 | .131 | 896 | .300 | .020 | 896 | .285 | .021 |
| 434 | 1.304 | .174 | 448 | 1.285 | | 952 | .326 | | 952 | .310 | |
| 448 | broke | | 455 | broke | | 1008 | broke | | 980 | broke | |
| ∴ Ultimate deflection =1.358. Broke ⅛ of an inch from the centre. | | | ∴ Ultimate deflection =1.318. Broke 1¼ inch from the centre. | | | ∴ Ultimate deflection =.351. Broke ⅜ of an inch from the centre. | | | ∴ Ultimate deflection =.322. Broke ¼ of an inch from the centre. | | |

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports | 7.058<br>7.017 | 15986000 | 433.1 | 1.372 | 594.2 |
| Experiment 2nd, bar 4ft. 6in. between supports | 7.080 | 15719000 | 421.8 | 1.365 | 575.7 |
| Mean | 7.051 | 15852500 | 427.4 | 1.368 | 584.9 |
| Experiment 3rd, bar 2ft. 3in. between sdpport | | | 920.8 | .364 | 335.1 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 875.7 | .338 | 296.0 |
| Mean | | | 898.2 | .351 | 315.5 |

Milton, No. 3, displays a circle of open crystals in the centre, surrounded by a compact frame of smaller granules.—It cuts and files with difficulty, and presents a fracture of a dull grey colour.—In the 4ft. 6in. bars, it is rather inferior in strength to the Level, and also in its flexure and power of resisting impact.

## No. X.

## ENGLISH IRONS.

### Elsicar, No. 2, Pig Iron, Cold Blast.

| *Experiment 1st.* | | | *Experiment 2nd.* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar...... 1.015<br>Breadth do........1.015<br>Distance between supports...... 4ft. 6in.<br>Weight of Bar 5ft. long, 15lbs. 8oz. | | | Depth of bar...... 1.036<br>Breadth do....... 1.000<br>Distance between supports .... 4ft. 6in,<br>Weight of bar 5ft. long, 15½lbs. | | | Depth of bar......1.030<br>Breadth do........1.006<br>Distance between supports .....2ft. 3in. | | | Depth of bar.... 1.024<br>Breadth do.......1.008<br>Distance between supports....2ft. 3in. | | |
| Weight in lbs. | Deflection in inches. | Deflection, Load removed, | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 56 | .151 | .008 | 56 | .153 | .007 | 112 | .030 | — | 112 | .040 | — |
| 126 | .365 | .025 | 126 | .375 | .027 | 224 | .073 | + | 224 | .088 | + |
| 182 | .577 | .058 | 182 | .563 | .062 | 336 | .115 | .005 | 336 | .140 | .006 |
| 238 | .81 | .094 | 238 | .784 | .090 | 448 | .165 | .009 | 448 | .200 | .011 |
| 294 | 1.075 | .149 | 294 | 1.054 | .153 | 560 | .222 | .014 | 560 | .264 | .020 |
| 350 | 1.387 | .224 | 350 | 1.338 | .21 | 672 | .290 | .025 | 672 | .341 | .034 |
| 406 | 1.74 | .327 | 406 | 1.68 | .31 | 784 | .351 | .036 | 784 | .428 | .060 |
| 434 | 1.94 | .395 | 462 | 2.09 | .44 | 896 | .434 | .065 | 812 | broke | |
| 469 | broke | | 476 | broke | | 924 | broke | | | | |
| ∴ Ultimate deflection = 2.147.<br>Broke one inch from the centre. | | | ∴ Ultimate deflection = 2.19.<br>Broke ¾ of an inch from the centre. | | | ∴ Ultimate deflection = .452.<br>Broke ½ an inch from the centre. | | | ∴ Ultimate deflection = .449.<br>Broke at the centre. | | |

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (b.) | Ultimate deflection (d.) | Product b x d or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | 6.932<br>6.936 | 12821000 | 448.5 | 2.179 | 977.2 |
| Experiment 2nd., bar 4ft. 6in. between supports | 6.916 | 12352000 | 443.5 | 2.269 | 1006.3 |
| Mean | 6.928 | 12586500 | 446.0 | 2.224 | 991.7 |
| Experiment 3rd., bar 2ft. 3in. between supports | | | 865.7 | .466 | 403.4 |
| Experiment 4th., bar 2ft. 3in. between supports | | | 768.2 | .460 | 353.3 |
| Mean | | | 816.9 | .463 | 378.3 |

This Iron has a vitrified and glutinous appearance over the entire section of the fracture; there is great uniformity in the size of the crystals, being nearly the same in the centre as those next the outer skin of the bar. It has a grey colour, intermixed with blue. Its working properties are of the first order, the action of filing being accompanied by a soft adhesive sound.*

* The comparative values of the Elsicar Cold Blast and the Milton Hot Blast Iron, will be found in my Report as given in the 7th volume of the Transactions of the British Association for the Advancement of Science.

## No. XI.

## ENGLISH IRON.

### Oldberry, No. 2, Pig Iron, Cold Blast.

<table>
<tr>
<td colspan="3">Experiment 1st.<br>Depth of Bar.... 1.063<br>Breadth do...... 1.006<br>Distance between supports .... 4ft. 6in.<br>Weight of bar 5ft. long, 16lbs. 5oz.</td>
<td colspan="3">Experiment 2nd<br>Depth of bar.... 1.038<br>Breadth do...... 1.009<br>Distance between supports .... 4ft. 6in<br>Weight of bar 5ft. lon,g 15¾lbs</td>
<td colspan="3">Experiment 3rd.<br>Depth of Bar.... 1.071<br>Breadth do....... 1·027<br>Distance between supports....... 2ft. 3in.</td>
<td colspan="3">Experiment 4th.<br>Depth of Bar.... 1·049<br>Beadth do........ 1.017<br>Distance between supports .... 2ft. 3in.</td>
</tr>
<tr>
<td>Weight in lbs.</td><td>Deflection in inches.</td><td>Deflection load removed.</td>
<td>Weight in lbs.</td><td>Deflection in inches.</td><td>Deflection load removed.</td>
<td>Weight in lbs.</td><td>Deflection in inches.</td><td>Deflection load removed.</td>
<td>Weight in lbs.</td><td>Deflection in inches.</td><td>Deflection load removed.</td>
</tr>
<tr><td>30</td><td>.063</td><td>+</td><td>30</td><td>.065</td><td>—</td><td>112</td><td>.029</td><td>—</td><td>112</td><td>.029</td><td>—</td></tr>
<tr><td>56</td><td>.125</td><td>.005</td><td>56</td><td>.124</td><td>+</td><td>224</td><td>.057</td><td>—</td><td>224</td><td>.060</td><td>+</td></tr>
<tr><td>112</td><td>.257</td><td>.014</td><td>112</td><td>.271</td><td>.010</td><td>336</td><td>.090</td><td>+</td><td>336</td><td>.095</td><td>+</td></tr>
<tr><td>168</td><td>.409</td><td>.032</td><td>168</td><td>.434</td><td>.030</td><td>448</td><td>.123</td><td>.005</td><td>448</td><td>.133</td><td>.005</td></tr>
<tr><td>224</td><td>.570</td><td>.055</td><td>224</td><td>.607</td><td>.053</td><td>560</td><td>.161</td><td>.007</td><td>560</td><td>.174</td><td>.009</td></tr>
<tr><td>280</td><td>.742</td><td>.083</td><td>280</td><td>.795</td><td>.084</td><td>672</td><td>.205</td><td>.014</td><td>672</td><td>.219</td><td>.014</td></tr>
<tr><td>336</td><td>.934</td><td>.119</td><td>336</td><td>1.002</td><td>.125</td><td>784</td><td>.250</td><td>.020</td><td>784</td><td>.267</td><td>.022</td></tr>
<tr><td>392</td><td>1.140</td><td>.167</td><td>392</td><td>1.230</td><td>.181</td><td>896</td><td>.300</td><td>:032</td><td>896</td><td>.326</td><td>.036</td></tr>
<tr><td>448</td><td>1.373</td><td>.240</td><td>448</td><td>1.495</td><td>.267</td><td>1008</td><td>.364</td><td>.050</td><td>008</td><td>.395</td><td>.056</td></tr>
<tr><td>504</td><td>1.661</td><td>.344</td><td>476</td><td>1.644</td><td></td><td>1064</td><td>.400</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>504</td><td>broke</td><td></td><td>1092</td><td>broke</td><td></td><td></td><td></td><td></td></tr>
<tr>
<td colspan="3">Broke ¼ of an inch from the centre, when the same weight was placed on again, after the deflection and elasticity had been taken.</td>
<td colspan="3">Ultimate deflection =1.788.<br>Broke 1¾ iuch from the centre.</td>
<td colspan="3">∴ Ultimate deflection =.416.<br>Broke ⅞ of an inch from the centre,</td>
<td colspan="3">The weight (1008) when replaced broke it ⅝ of an inch from the centre.</td>
</tr>
</table>

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | 7.037 / 7.059 | 14198000 | 443.4 | 1.766 | 783.0 |
| Experiment 2nd, bar 4ft. 6in. between supports | 7.080 | 14417000 | 463.6 | 1.856 | 860.4 |
| Mean | 7.059 | 14307500 | 453.5 | 1.811 | 821.7 |
| Experiment 3rd, bar 2ft. 3in. between supports | | | 927.0 | .446 | 413.4 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 900.6 | .414 | 373.8 |
| Mean | | | 913.8 | .430 | 393.1 |

Oldberry, No. 2, surrounds the middle of the fracture wtth a band of small compact crystals, in colour a dark grey; rather porous in the centre, but in other respects sound and perfect.—It is similar in its power of being worked to the Masteg, South Welsh Iron.—It cuts freely with the chisel, and is easily reduced by the file.

# No. XII.

## ENGLISH IRONS.

### Old Park, , No. 2, Pig Iron, Cold Blast.

*Experiment 1st.*
Depth of Bar . . . . . .1.54
Breadth do. . . . . . . . 1.47
Distance between supports. . . . . .4ft. 6in
Weight of Bar 5ft. long, 34½lbs.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .014 | — |
| 56 | .027 | — |
| 112 | .054 | + |
| 224 | .113 | .005 |
| 336 | .179 | .011 |
| 448 | .249 | .019 |
| 560 | .322 | .029 |
| 672 | .399 | .038 |
| 784 | .478 | .052 |
| 896 | .569 | .068 |
| 1008 | .655 | .081 |
| 1120 | .748 | .103 |
| 1232 | .860 | .131 |
| 1344 | .975 | .167 |
| 1400 | 1.038 | |
| 1456 | broke | |

∴ Ultimate deflection =1.097.
Broke [illegible] of an inch from the centre.

*Experiment 2nd.*
Depth of Bar. . . . . . 1.033
Breadth do. . . . . . . 1.005
Distance between supports. . . . . 4ft. 6in.
Weight of Bar 5ft. long, 15lbs. 10oz.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .065 | — |
| 56 | .135 | — |
| 112 | .265 | .011 |
| 168 | .427 | .028 |
| 244 | .595 | .050 |
| 280 | .782 | .080 |
| 336 | .984 | .119 |
| 392 | 1.205 | .163 |
| 420 | 1.320 | |
| 448 | broke | |

∴ Ultimate deflection =1.435.
Broke at the centre,

*Experiment 3rd.*
Depth of Bar. . . . . .1.036
Breadth do. . . . . . .1.012
Distance between supports. . . . . . 4ft. 6in
Weight of bar 5ft. long, 16¾lbs

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .068 | — |
| 56 | .140 | — |
| 112 | .276 | .019 |
| 168 | .427 | .030 |
| 224 | .600 | .055 |
| 280 | .778 | .080 |
| 336 | .976 | .111 |
| 392 | 1.185 | .155 |
| 448 | 1.421 | .213 |
| 504 | 1.700 | .295 |

Broke 1¼ of an inch from the centre after the weight (504) had been dut on again.

*Experiment 4th.*
Depth of Bar. . . . .1.025
Breadth do . . . . . .1.000
Distance between supports . . . . 2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .032 | — |
| 224 | .066 | — |
| 336 | .103 | .005 |
| 448 | .143 | .007 |
| 560 | .185 | .010 |
| 672 | .235 | .019 |
| 784 | .286 | .025 |
| 896 | .345 | .035 |
| 1008 | .407 | .251 |
| 1064 | broke | |

∴ Ultimate deflection. =.435.
Broke ¾ an inch from the eentre.

*Experiment 5th.*
Depth of Bar. . . . .1.005
Breadth do . . . . . .1.005
Distance between Supports. . . . .2ft. 3in.

| Weight in lbs, | Deflection in inches. | Deflection load removed, |
|---|---|---|
| 112 | .033 | — |
| 224 | .069 | — |
| 336 | .105 | + |
| 448 | .146 | .006 |
| 560 | .188 | .009 |
| 672 | .230 | .012 |
| 784 | .281 | .020 |
| 896 | .344 | .031 |
| 1008 | .410 | .050 |
| 1064 | .450 | |
| 1120 | broke | |

∴ Ultimate deflection =.487.
Broke ¼ of an inch from the centre.

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, ($b$.) | Ultimate deflection, ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ............ | | | 417.7 | 1.689 | 705.6 |
| Mean .............................. | | | | | |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.072 / 7.017 | 15018000 | 417.8 | 1.482 | 619.2 |
| Experiment 3rd., bar 4ft. 6in. between supports............ | 7.059 | 14196000 | 464.0 | 1.761 | 817.2 |
| Mean .............................. | 7.049 | 14607000 | 440.9 | 1.621 | 718.2 |
| Experiment 4th., bar 2ft. 3in. between supports............ | | | 1013.0 | .457 | 462.90 |
| Experiment 5th., bar 2ft. 3in. between supports............ | | | 1103.0 | .490 | 540.47 |
| Mean.............................. | | | 1058.0 | .473 | 501.68 |

Comparing this Iron with the preceding, it appears closer-grained, accompanied with more lustre.—Characteristics, a grey colour, with a remarkable degree of softness when cut with the tool; it also files with great ease, and may be classed with some of our softest metals.

## No. XIII.

## ENGLISH IRON.

### Horace St. Pauls, Windmill End, No. 2, Pig Iron, Cold Blast, Staffordshire.

| *Experiment 1st* | | | *Experiment 2nd* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar.... 1.043<br>Breadth do...... 1.024<br>Distance between supports.... 4ft. 6in<br>Weight of bar 5ft. long, 16¼lbs | | | Depth of bar.... 1.038<br>Breadth do...... 1.010<br>Distance between supports.... 4ft. 6in<br>Weight of bar 5ft. long, 15¾lbs | | | Depth of Bar.... 1.059<br>Breadth do....... 1.021<br>Distance between supports....... 2ft. 3in. | | | Depth of bar.... 1.045<br>Breadth do...... 1.020<br>Distance between supports.... 2ft. 3in. | | |
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 56 | .110 | — | 56 | .115 | + | 112 | .025 | — | 112 | .028 | — |
| 112 | .227 | + | 112 | .240 | .009 | 224 | .060 | — | 224 | .066 | + |
| 168 | .352 | .013 | 126 | .274 | .011 | 336 | .090 | + | 336 | .094 | + |
| 224 | .490 | .029 | 182 | .412 | .02[illegible] | 448 | .125 | .005 | 448 | .130 | .005 |
| 280 | .630 | .045 | 238 | .560 | .042 | 560 | .160 | .007 | 560 | .167 | .008 |
| 336 | .789 | .066 | 294 | .719 | .064 | 672 | .196 | .010 | 672 | .206 | .011 |
| 392 | .955 | .094 | 350 | .107 | .091 | 784 | .240 | .017 | 784 | .255 | .020 |
| 448 | 1.140 | .125 | 406 | 1.279 | .12[illegible] | 896 | .285 | .024 | 896 | .295 | .027 |
| 504 | 1.350 | .187 | 462 | 1.394 | .170 | 1008 | .336 | .036 | 1008 | .352 | .042 |
| | | | 490 | broke | .204 | 1120 | .398 | .059 | 1036 | broke | |
| 560 | 1.589 | .260 | 504 | | | 1176 | .431 | | | | |
| | | | | | | 1204 | broke | | | | |
| Broke at the centre. | | | Ultimate deflection =1.45<br>Broke ⅜ of an inch from the centre. | | | ∴ Ultimate deflection =.447.<br>Broke ⅓ of an inch from the centre. | | | ∴ Ultimate deflection =.364.<br>Broke ¼ of an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ............ | 7.080 | 16717000 | 502.7 | 1.657 | 833.0 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | {7.059 {7.075 | 16263000 | 463.2 | 1.505 | 697.1 |
| Mean ................................ | 7.071 | 16490000 | 482.9 | 1.581 | 765.0 |
| Experiment 3rd., bar 2ft. 3in. between supports ............ | | | 1053. | .473 | 498.0 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 930.1 | .380 | 353.4 |
| Mean................................ | | | 991.5 | .426 | 425.7 |

The fracture has a firm compact appearance.—Crystallization very minute at the edges of the bar, and surrounded with a hard skin.—Colour a dark grey; resists cutting with tenacity, but yields more freely to the file.—Windmill End is decidedly a strong iron, but more difficult to be worked than either the Old Park or Low Moor irons.

## No. XIV.

## ENGLISH IRONS.

### Ley's Works, No. 1, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of Bar...... .998 Breadth do.........1.006 Distance between supports......4ft. 6in. Weight of Bar 5ft. long, 15lbs. | | | *Experiment 2nd.* Depth of bar...... 1.009 Breadth do....... 1.025 Distance between supports ....4ft. 6in, Weight of bar 5ft. long, 15lbs. 6oz. | | | *Experiment 3rd.* Depth of bar ......1.016 Breadth do........1.004 Distance between supports .....4ft. 6in. Weight of bar 5ft. long, 15lbs. 5oz | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection, Load removed. | Deflection in inches. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .089 | — | 28 | .084 | — | 28 | .084 | — |
| 56 | .177 | .009 | 56 | .170 | .006 | 56 | .169 | .007 |
| 112 | .385 | .035 | 112 | .363 | .030 | 112 | .360 | .029 |
| 168 | .614 | .074 | 168 | .588 | .062 | 168 | .590 | .060 |
| 224 | .884 | .117 | 224 | .820 | .101 | 224 | .846 | .103 |
| 280 | 1.187 | .170 | 280 | 1.098 | .145 | 280 | 1.124 | .152 |
| 336 | 1.519 | .251 | 336 | 1.408 | .215 | 336 | 1.415 | .216 |
| 364 | 1.710 | | 392 | 1.760 | .312 | 392 | 1.780 | .321 |
| 392 | broke | | 406 | broke | | 413 | broke | |
| ∴ Ultimate deflection =1.882. Broke ½ an inch from the centre. | | | ∴ Ultimate deflection =1.843. Broke ½ an inch from the centre. | | | ∴ Ultimate deflection =.1 903 Broke ⅝ of an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight (*b.*) | Ultimate deflection (*d.*) | Product *b* X *d* or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports............. | { 6.979 6.997 | 11452000 | 391.2 | 1.878 | 734.7 |
| Experiment 2nd, bar 4ft. 6in. between supports............ | 6.916 | 11535000 | 389.1 | 1.859 | 723.3 |
| Experiment 3rd, bar 4ft. 6in. between support............. | 6.936 | 11631000 | 398.5 | 1.933 | 770.4 |
| | 6.957 | 11539333 | 392.9 | 1.890 | 742.8 |

Leys Works, Hot Blast, is a weak iron as respects its breaking weights, but evidently stands well in its power of resistance to the force of impact, it exhibits a porous uniform fracture, cuts with freedom, and yields freely to the file.

I should consider this a valuable metal for reducing the harder irons, and adapted for light work where strength is not required.

## No. XV.
## ENGLISH IRON.
### Lane End, No. 2, Pig Iron.

| *Experiment 1st.* Depth of Bar.... 1.005 Breadth do...... 1.007 Distance between supports .... 4ft. 6in. Weight of bar 5ft. long, 15lbs. 7oz. | | | *Experiment 2nd.* Depth of bar.... .995 Breadth do...... 1.020 Distance between supports .... 4ft. 6in. Weight of bar 5ft. lon,g 15lbs. 6oz. | | | *Experiment 3rd.* Depth of Bar.... 1.016 Breadth do....... 1-028 Distance between supports....... 4ft. 6in. Weight of bar 5ft. long, 15lbs. 9oz | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .070 | — | 28 | .070 | — | 28 | .070 | — |
| 56 | .140 | — | 56 | .142 | — | 56 | .137 | — |
| 112 | .281 | .011 | 112 | .289 | .012 | 112 | .243 | .007 |
| 168 | .447 | .027 | 168 | .458 | .027 | 168 | .430 | .021 |
| 224 | .610 | .043 | 224 | .628 | .040 | 224 | .592 | .038 |
| 280 | .780 | .061 | 280 | .800 | .060 | 280 | .760 | .051 |
| 336 | .965 | .082 | 336 | .998 | .082 | 336 | .945 | .075 |
| 392 | 1.160 | .110 | 392 | 1.198 | .110 | 392 | 1.138 | .100 |
| 448 | 1.370 | .143 | 420 | 1.308 | | 448 | 1.340 | :131 |
| 476 | broke | | 448 | broke | | | | |
| Ultimate deflection =1.471 Broke at the centre. | | | ,·. Ultimate deflection =1.411. Broke ½ an inch from the centre. | | | Broke at the centre. | | |

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | 7.000 / 7.017 | 15350000 | 468.0 | 1.478 | 691.7 |
| Experiment 2nd, bar 4ft. 6in. between supports. | 7.017 | 15184000 | 443.6 | 1.404 | 622.8 |
| Experiment 3rd, bar 4ft. 4in. between supports | 7.080 | 16829000 | 422.1 | 1.361 | 574.7 |
| Mean | 7.028 | 15787666 | 444.5 | 1.414 | 629.7 |

Lane End, No. 2, is a stronger iron than Leys, and equally fluid. When cast in large masses it collapses and shrinks rapidly when cooling. It presents a fine crystalline appearance; open grained and easily reduced by the file. In many respects it is similar to the Leys, but inferior in its power of resisting impact.

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## No. XVI.
## ENGLISH IRONS.
### Carroll, No. 2, Pig Iron, Cold Blast.

| *Experiment 1st.*<br>Depth of Bar .....1.050<br>Breadth do....... 1.010<br>Distance between supports......4ft. 6in.<br>Weight of Bar 5ft. long, 16lbs. 10oz. | | | *Experiment 2nd.*<br>Depth of Bar...... 1.025<br>Breadth do....... 1.015<br>Distance between supports..... 4ft. 6in.<br>Weight of Bar 5ft. long, 16lbs. | | | *Experiment 3rd.*<br>Depth of Bar...... 1.069<br>Breadth do.. ..... ..1.020<br>Distance between supports..... 2ft. 3in. | | | *Experiment 4th.*<br>Depth of Bar..... 1.030<br>Breadth do ...... 1.044<br>Distance between supports .... 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 112 | .225 | .008 | 56 | .112 | + | 112 | .026 | — | 112 | .028 | — |
| 126 | .256 | .010 | 112 | .233 | .008 | 224 | .054 | — | 224 | .060 | — |
| 182 | .384 | .019 | 126 | .264 | .010 | 336 | .083 | + | 336 | .090 | + |
| 238 | .518 | .035 | 182 | .398 | .016 | 448 | .112 | + | 448 | .124 | .005 |
| 294 | .659 | .052 | 238 | .534 | .033 | 560 | .149 | .006 | 560 | .159 | .007 |
| 350 | .810 | .073 | 294 | .683 | .052 | 672 | .183 | .007 | 672 | .196 | .010 |
| 406 | .870 | .099 | 350 | .840 | .073 | 784 | .224 | .016 | 784 | .234 | .014 |
| 462 | 1.144 | .133 | 406 | 1.008 | .110 | 896 | .262 | .020 | 896 | .278 | .021 |
| 476 | broke | | 434 | 1.097 | .118 | 952 | .284 | | 952 | broke | |
| | | | 448 | 1.144 | | 1009 | broke | | | | |
| | | | 462 | broke | | | | | | | |
| ∴ Ultimate deflection =1.183.<br>Broke at the centre. | | | ∴ Ultimate deflection =1.191.<br>Broke ¾ of an inch from the centre. | | | ∴ Ultimate deflection =.305.<br>Broke ¼ of an inch from the centre. | | | ∴ Ultimate deflection. =.299.<br>Broke ¾ of an inch from the centre. | | |

| Results reduced to those of Bars 1.00 inch square. | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, ($b$) | Ultimate deflection, ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports............. | 7.080 | 16760000 | 427.5 | 1.242 | 531.0 |
| Experiment 2nd., bar 4ft. 6in. between supports............. | 7.059 | 17312000 | 433.2 | 1.221 | 529.0 |
| Mean.............................. | 7.069 | 17036000 | 430.3 | 1.231 | 530.0 |
| Experiment 3rd., bar 2ft. 3in. between supports............. | | | 864.8 | .326 | 281.9 |
| Experiment 4th., bar 2ft. 3in. between supports............. | | | 859.6 | .308 | 264.7 |
| Mean.............................. | | | 817.2 | .317 | 273.3 |

The Carroll is analogous to the Varteg (Welsh) iron in its density and crystalline structure. It has less lustre, and presents features of hardness when acted upon by the chisel or turning tool; it however files with more ease than that iron.

# No. XVII.

## ENGLISH IRONS.

### Bierly, No. 2, Pig Iron, Bradford, Yorkshire.

| *Experiment 1st.* Depth of Bar.... 1.016 Breadth do......1.044 Distance between supports .... 4ft. 6in. | | | *Experiment 2nd.* Depth of bar.... 1.034 Breadth do...... 1.034 Distance between supports .... 4ft. 6in. | | | *Experiment 3rd.* Depth of Bar .... 1.021 Breadth do........1.031 Distance between supports....... 4ft. 6in, | | | *Experiment 4th.* Depth of Bar...... 1.007 Breadth do........1.035 Distance between supports......2ft. 3in. | | | *Experiment 5th.* Depth of bar...... 1.025 Breadth do....... 1.034 Distance between supports .... 2ft. 3in, | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .061 | | 28 | .061 | | 28 | .060 | | 112 | .032 | + | 112 | .030 | + |
| 56 | .126 | + | 56 | .125 | + | 56 | .119 | — | 224 | .064 | + | 224 | .061 | + |
| 112 | .284 | .012 | 112 | .249 | .012 | 112 | .240 | .009 | 336 | .098 | .005 | 336 | .095 | + |
| 168 | .387 | .023 | 168 | .389 | .021 | 168 | .376 | .019 | 448 | .137 | .006 | 448 | .132 | .005 |
| 224 | .538 | .039 | 224 | .540 | .040 | 224 | .520 | .037 | 560 | .177 | .008 | 560 | .171 | .008 |
| 280 | .697 | .061 | 280 | .700 | .061 | 280 | .680 | .058 | 672 | .219 | .014 | 672 | .213 | .013 |
| 336 | .862 | .088 | 336 | .862 | .089 | 336 | .834 | .081 | 784 | .265 | .021 | 784 | .256 | .020 |
| 392 | 1.050 | .122 | 392 | 1.049 | .121 | 392 | 1.013 | .117 | 896 | .323 | .036 | 896 | broke | |
| 420 | 1.147 | | 420 | 1.152 | broke | 420 | 1.108 | | 952 | broke | | | | |
| 448 | broke | | | | | 448 | broke | | | | | | | |
| Ultimate deflection =1,237 Broke 1⅝ of an inch from the centre. | | | Broke ⅛ of an inch from the centre, | | | ∵ Ultimate deflection =1.194. Broke one inch from the centre. | | | ∴ Ultimate deflection =.346. Broke ⅜ of an inch from the centre. | | | ∴ Ultimate deflection =1.237. Broke ½ an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports .......... | 7185 | 16237000 | 415.7 | 1.257 | 522.5 |
| Experiment 2nd., bar 4ft. 6in. between supports.......... | | 15490000 | 379.9 | 1.191 | 452.5 |
| Experiment 3rd., bar 4ft. 6in. between supports .......... | | 16741400 | 416.8 | 1.219 | 508.1 |
| Mean.............................. | | 16156133 | 404.1 | 1.222 | 494.3 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 907.0 | .3484 | 316.0 |
| Experiment 5th, bar 2ft. 3in. between supports............ | | | 824.8 | .3034 | 250.2 |
| Mean.............................. | | | 865.9 | .3259 | 283.1 |

Bierley, No. 2, Yorkshire, is rather closer grained than the Low Moor, but in other respects very similar in appearance and in its power of being worked.

## No. XVIII.

## ENGLISH IRONS.

### W. S. S., No. 2, Pig Iron. Staffordshire.

| *Experiment 1st* Depth of Bar....1.021 Breadth do......1.015 Distance between supports....4ft. 6in. | | | *Experiment 2nd* Depth of bar....1 003 Breadth do......1.012 Distance between supports....4ft. 6in | | | *Experiment 3rd.* Depth of Bar....1.015 Breadth do....... ·995 Distance between supports.......4ft. 6in. | | | *Experiment 4th.* Depth of Bar......1.011 Breadth do........1.033 Distance between supports......2ft. 3in. | | | *Experiment 5th.* Depth of bar......1.011 Breadth do......1.022 Distance between supports ....2ft. 3in, | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .067 | | 28 | .068 | | 28 | .072 | | 112 | .033 | + | 112 | .035 | + |
| 56 | .134 | + | 56 | .138 | + | 56 | .146 | .005 | 224 | .067 | + | 224 | .070 | + |
| 112 | .270 | .010 | 112 | .279 | .012 | 112 | .297 | .015 | 336 | .106 | + | 336 | .106 | .005 |
| 168 | .429 | .020 | 168 | .440 | .028 | 168 | .466 | .029 | 448 | .149 | .006 | 448 | .150 | .007 |
| 224 | .572 | .032 | 224 | .607 | .046 | 224 | .644 | .048 | 560 | .194 | .010 | 560 | .192 | .010 |
| 280 | .754 | .053 | 280 | .779 | .064 | 280 | .833 | .070 | 672 | .241 | .015 | 672 | .236 | .013 |
| 336 | .942 | .078 | 336 | .970 | .090 | 336 | 1.048 | .099 | 784 | .295 | .025 | 784 | .283 | .020 |
| 392 | 1.139 | .108 | 392 | 1.179 | .121 | 364 | 1.154 | | 896 | .350 | .035 | 896 | .338 | .028 |
| 420 | 1.248 | — | 420 | 1.281 | — | 392 | 1.264 | broke | 952 | broke | | 924 | broke | — |
| 448 | broke | | 441 | broke | | | | | | | | | | |
| Ultimate deflection =1 347 Broke at the centre. | | | ∴ Ultimate deflection =1.356. Broke ¾ of an inch from the centre | | | Broke ⅛ of an inch from the centre, | | | ∴ Ultimate deflection =.375. Broke 1⅜ inch from the centre. | | | ∴ Ultimate deflection =.350. Broke one inch from the centre | | |

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | 7.041 | 15116000 | 423.4 | 1.375 | 582.2 |
| Experiment 2nd, bar 4ft. 6in. between supports. | | 15476000 | 433.2 | 1.360 | 589.1 |
| Experiment 3rd, bar 4ft. 6in. between supports. | | 14268000 | 382.4 | 1.283 | 490.6 |
| Mean | | 14953333 | 413.0 | 1.33 9 | 553.9 |
| Experiment 4th, bar 2ft. 3in. between supports. | | | 901.6 | .3791 | 341.8 |
| Experiment 5th, bar 2ft. 3in. between supports. | | | 884.5 | .3538 | 313.0 |
| Mean | | | 893.0 | .3664 | 327.4 |

This iron has an appearance in its fracture identically the same as the Apedale. It chips with great freedom, but has a hard and gritty feel under the file.—Colour light gray.

## No. XIX.
## ENGLISH IRONS.

Coltham, B. F., No. 1, Pig Iron, Hot Blast. Staffordsh're

| *Experiment 1st.* Depth of Bar .....1.010 Breadth do....... 1.005 Distance between supports......4ft. 6in | | | *Experiment 2nd.* Depth of Bar...... 1.005 Breadth do....... 1.013 Distance between supports..... 4ft. 6in. | | | *Experiment 3rd.* Depth of Bar......1.036 Breadth do.. .... ..1.008 Distance between supports.....4ft. 6in. | | | *Experiment 4th.* Depth of Bar.....1.015 Breadth do ......1.009 Distance between supports .... 2ft. 3in. | | | *Experiment 5th.* Depth of bar .....1.009 Breadth do.......1.015 Distance between supports ....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed. |
| 28 | .070 | | 28 | .067 | | 28 | .062 | | 112 | .034 | + | 112 | .032 | |
| 56 | .138 | + | 56 | .137 | + | 56 | .125 | + | 224 | .069 | + | 224 | .067 | + |
| 112 | .277 | .017 | 112 | .278 | .013 | 112 | .250 | .012 | 336 | .107 | .005 | 336 | .105 | + |
| 168 | .440 | .032 | 168 | .448 | .030 | 168 | .397 | .023 | 448 | .149 | .007 | 448 | .149 | .006 |
| 244 | .603 | .049 | 224 | .609 | .050 | 224 | .547 | .040 | 560 | .193 | .010 | 560 | .191 | .009 |
| 280 | .777 | .072 | 280 | .788 | .074 | 280 | .703 | .059 | 672 | .236 | .015 | 672 | .235 | .014 |
| 336 | .968 | .102 | 336 | .981 | .106 | 336 | .869 | .082 | 784 | broke | | 784 | .285 | .022 |
| 392 | 1.172 | .140 | 392 | 1.190 | .145 | 392 | 1.049 | .110 | | | | 812 | broke | |
| 448 | 1.408 | .193 | 420 | 1.305 | | 448 | 1.245 | .150 | | | | | | |
| 469 | broke | | 441 | broke | | 504 | 1.467 | .208 | | | | | | |
| | | | | | | 546 | broke | | | | | | | |
| ∴ Ultimate deflection =1.489 Broke 3/4 of an inch from the centre. | | | ∴ Ultimate deflection =1.383. Broke 6/8 of an inch from the centre. | | | ∴ Ultimate deflection =1.644. Broke 3/8 of an inch from centre. | | | ∴ Ultimate deflection. =.278. Broke 4/8 of an inch from the centre. | | | ∴ Ultimate deflection =.296 Broke at the centre. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, ($b$) | Ultimate deflectiou ($d$) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | 7128 | 15371900 | 457.5 | 1.504 | 688.0 |
| Experiment 2nd., bar 4ft. 6in. between supports | | 15423600 | 431.0 | 1.390 | 599.1 |
| Experiment 3rd., bar 4ft. 6in. between supports | | 15734700 | 504.7 | 1.703 | 859.5 |
| Mean | | 15510066 | 464.4 | 1.532 | 715.5 |
| Experiment 4th., bar 2ft. 3in. between supports | | | 754.2 | .2822 | 2 12.8 |
| Experiment 5th., bar 2ft. 3in. between supports | | | 785.8 | .2986 | 234.6 |
| Mean | | | 770.0 | .2904 | 223.7 |

The Coltham iron has its interior granules encased with a frame-work of minute crystals surrounding the edge of the bar.—Colour nearly similar to that of the W. S. S., with rather a whiter appearance.

This iron is worked with perfect freedom, and has a less gritty sensation under the file than the W. S. S.

## No. XX.
## ENGLISH IRONS.

Corbyn's Hall, No. 2, Pig Iron. Near Dudley, Staffordshire.

| *Experiment 1st.* Depth of Bar....1.016 Breadth do......1.025 Distance between supports....4ft. 6in. | | | *Experiment 2nd.* Depth of bar....1.025 Breadth do......1.018 Distance between supports....4ft. 6in. | | | *Experiment 3rd.* Depth of Bar....1.039 Breadth do.......1.024 Distance between supports.......4ft. 6in, | | | *Experiment 4th.* Depth of Bar......1.036 Breadth do........1.005 Distance between supports......2ft. 3in. | | | *Experiment 5th.* Depth of bar......1.016 Breadth do......1.013 Distance between supports ....2ft. 3in, | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs, | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .070 | | 28 | .069 | | 28 | .069 | | 112 | .033 | + | 112 | .035 | + |
| 56 | .139 | + | 56 | .139 | + | 56 | .138 | + | 224 | .070 | + | 224 | .072 | + |
| 112 | .286 | .013 | 112 | .291 | .014 | 112 | .287 | .019 | 336 | .110 | .005 | 336 | .116 | .006 |
| 168 | .459 | .030 | 168 | .478 | .039 | 168 | .460 | .039 | 448 | .156 | .009 | 448 | .161 | .010 |
| 224 | .642 | .053 | 224 | .674 | .068 | 224 | .641 | .064 | 560 | .201 | .012 | 560 | .210 | .014 |
| 280 | .838 | .080 | 280 | .868 | .094 | 280 | .828 | .091 | 672 | .248 | .017 | 672 | .258 | .019 |
| 336 | 1.048 | .112 | 336 | 1.090 | .131 | 336 | 1.039 | .123 | 784 | .300 | .025 | 784 | .315 | .026 |
| 392 | 1.282 | .159 | 392 | 1.348 | .187 | 392 | 1.259 | .168 | 896 | .363 | .036 | 896 | .379 | .040 |
| 448 | 1.544 | .219 | 448 | 1.637 | .260 | 448 | 1.516 | .224 | 952 | .395 | | 924 | broke | |
| 455 | broke | | | | | 476 | 1.657 | | 1008 | broke | | | | |
| | | | | | | 490 | broke | | | | | | | |
| ∴ Ultimate deflection =1.574. Broke ⅜ of an inch from the centre. | | | Broke one inch from the centre after the weight (448) had been replaced. | | | ∴ Ultimate deflection =1.719. Broke ½ an inch from the centre. | | | ∴ Ultimate deflection =.423 Broke ¼ of an inch from the centre. | | | ∴ Ultimate deflection =.393. Broke ½ an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports | 7007 | 14340600 | 430.0 | 1.599 | 687.6 |
| Experiment 2nd, bar 4ft. 6in. between supports | | 13821000 | 418.9 | 1.678 | 702.9 |
| Experiment 3rd, bar 4ft. 6in. between supports | | 13376000 | 443.2 | 1.786 | 791.7 |
| Mean | | 13845866 | 430.7 | 1.687 | 727.4 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 934.5 | .4382 | 409.5 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 883.6 | .3993 | 352.8 |
| Mean | | | 909.0 | .4187 | 381.1 |

The fracture of this iron is remarkable for its regularity, all the particles being nearly of equal size.—It is a free open iron, combining fluidity and softness under the chisel and the file.

## No. XXI.
## ENGLISH IRONS.

Wall-Brook, No. 3, Pig Iron, Dudley Worcestershire.

| *Experiment 1st.* Depth of Bar .....1.025 Breadth do.......1.026 Distance between supports......4ft. 6in. | | | *Experiment 2nd.* Depth of Bar...... 1.011 Breadth do....... 1.044 Distance between supports..... 4ft. 6in. | | | *Experiment 3rd.* Depth of Bar......1.038 Breadth do.. .... ..1.029 Distance between supports.....4ft. 6in. | | | *Experiment 4th.* Depth of Bar.....1.031 Breadth do ......1.024 Distance between supports .... 2ft. 3in. | | | *Experiment 5th.* Depth of bar.......1.038 Breadth do.. .....1.012 Distance between supports ....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed. |
| 28 | .064 | | 28 | .060 | | 28 | .061 | | 112 | .030 | + | 112 | .030 | + |
| 56 | .127 | .006 | 56 | .127 | + | 56 | .122 | + | 224 | .064 | + | 224 | .062 | + |
| 112 | .256 | .017 | 112 | .253 | .012 | 112 | .248 | .010 | 336 | .095 | .005 | 336 | .099 | .006 |
| 168 | .407 | .031 | 168 | .400 | .029 | 168 | .397 | .023 | 448 | .134 | .006 | 448 | .137 | .007 |
| 224 | .559 | .050 | 224 | .555 | .049 | 224 | .553 | .047 | 560 | .173 | .009 | 560 | .176 | .010 |
| 280 | .722 | .073 | 280 | .721 | .072 | 280 | .718 | .069 | 672 | .214 | .014 | 672 | .218 | .015 |
| 336 | .910 | .110 | 336 | .902 | .104 | 336 | .894 | .095 | 784 | .259 | .020 | 784 | .264 | .024 |
| 392 | 1.092 | .139 | 392 | 1.090 | .141 | 392 | 1.082 | .134 | 896 | .309 | .030 | 896 | .317 | .034 |
| 448 | 1.198 | — | 428 | 1.300 | .190 | 448 | 1.300 | .182 | 952 | .337 | | 952 | broke | |
| | broke | | 476 | broke | | 476 | 1.412 | — | 1008 | .366 | | | | |
| | | | | | | 497 | broke | — | | | | | | |
| ∴ Ultimate deflection =1.293 Broke $1\frac{1}{3}$ inch from the centre. | | | ∴ Ultimate deflection =1.398. Broke $\frac{1}{3}$ an inch from the centre. | | | ∴ Ultimate deflection =1.490. Broke $\frac{3}{4}$ of an inch from centre. | | | Broke $\frac{1}{4}$ of (an inch from the centre. | | | ∴Ultimate deflection =.340. Broke $\frac{3}{4}$ of an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | 6979 | 15587600 | 415.6 | 1.325 | 550.7 |
| Experiment 2nd, bar 4ft. 6in. between supports | | 15148400 | 431.9 | 1.459 | 630.1 |
| Experiment 3rd, bar 4ft. 6in. between supports | | 15448300 | 448.3 | 1.546 | 693.1 |
| Mean | | 15394766 | 431.9 | 1.443 | 624.6 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 926.1 | .3773 | 349.4 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 873.1 | .3529 | 308.1 |
| Mean | | | 899.6 | .3651 | 328.7 |

This Iron when fractured is very similar in appearance to the Pant; it is pretty uniform in its texture, but works with a feeling of hardness.—Colour light gray intermixed with blue.

## No. XXII.

## ENGLISH IRONS.

### Oldberry, No. 3, Pig Iron, Hot Blast, (Patent Iron,) Shropshire.

*Experiment 1st.*
Depth of Bar.... .992
Breadth do......1.000
Distance between supports.... 4ft. 6in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .055 | |
| 56 | .105 | |
| 112 | .198 | |
| 168 | .295 | + |
| 224 | .399 | .010 |
| 280 | .501 | .014 |
| 336 | .610 | .020 |
| 392 | .716 | .027 |
| 448 | .821 | .032 |
| 504 | .938 | .040 |
| 560 | 1.058 | .051 |
| 588 | broke | — |

∴ Ultimate deflection = 1,116.
Broke at centre.

*Experiment 2nd*
Depth of bar.... 1.010
Breadth do...... .996
Distance between supports .... 4ft. 6in

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .049 | |
| 56 | .097 | |
| 112 | .189 | + |
| 168 | .281 | .008 |
| 224 | .384 | .010 |
| 280 | .487 | .012 |
| 336 | .588 | .016 |
| 392 | .690 | .021 |
| 448 | .790 | .029 |
| 504 | .904 | .036 |
| 532 | broke | |

∴ Ultimate deflection = .957.
Broke $\frac{3}{4}$ of an inch from the centre.

*Experiment 3rd.*
Depth of Bar.... 1.006
Breadth do.......1.006
Distance between supports....... 4ft. 6in,

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .050 | |
| 56 | .099 | + |
| 112 | .190 | + |
| 168 | .283 | .008 |
| 224 | .384 | .010 |
| 280 | .488 | .016 |
| 336 | .590 | .020 |
| 392 | .698 | .029 |
| 448 | .800 | .032 |
| 504 | .911 | .042 |
| 518 | broke | |

∴ Ultimate deflection = .938.
Broke $\frac{5}{8}$ an inch from the centre.

*Experiment 4th.*
Depth of Bar...... .991
Breadth do........ .991
Distance between supports......2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
|---|---|---|
| 112 | .026 | |
| 224 | .052 | + |
| 336 | .075 | + |
| 448 | .100 | + |
| 560 | .131 | + |
| 672 | .158 | + |
| 784 | .187 | .005 |
| 896 | .215 | .006 |
| 1008 | broke | |

∴ Ultimate deflection = .244
Broke $\frac{3}{4}$ of an inch from the centre.

*Experiment 5th.*
Depth of bar...... 1.004
Breadth do....... .993
Distance between supports .... 2ft. 3in,

| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
|---|---|---|
| 112 | .024 | |
| 224 | .045 | |
| 336 | .068 | |
| 448 | .091 | |
| 560 | .117 | + |
| 672 | .143 | + |
| 784 | .168 | + |
| 896 | .194 | .005 |
| 1008 | .220 | .005 |
| 1036 | broke | |

∴ Ultimate deflection = .227.
Broke $\frac{3}{8}$ of an inch from the centre.

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs. | Breaking Weight, ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | 7300 | 22810700 | 597.5 | 1.107 | 661.5 |
| Experiment 2nd., bar 4ft. 6in. between supports | | 22733000 | 523.6 | .966 | 506.0 |
| Experiment 3rd., bar 4ft. 6in. between supports | | 22656500 | 508.8 | .9436 | 480.1 |
| Mean | | 22733400 | 543.3 | 1.0055 | 549.2 |
| Experiment 4th., bar 2ft. 3in. between supports | | | 1036 | .2414 | 250.5 |
| Experiment 5th., bar 2ft. 3in. between supports | | | 1035 | .2279 | 235.9 |
| Mean | | | 1035 | .2346 | 243.2 |

Only one sample of this Iron was obtained, and portions of it when viewed with the naked eye presented a speckled white appearance. When examined with a microscope it seems to be a metal unequally mixed, and presents in the same fracture two distinct processes of crystallization, the greater proportion being pure white, and the other a bluish gray, projecting more prominent than the rest on the face of the fracture. In the above samples, the white band of crystals prevented them being worked.

The results obtained from the preceeding experiments on the English irons, seem to furnish the best evidence that can be procured on the strength andother qualities investigated in this enquiry.

On examination it will be found that considerable differences exist between one iron and another, but not more than the nature of the ores and their products would indicate. During the smelting process, the same qualities of iron are not always produced, as the Nos. 1, 2, and 3, and sometimes No. 4, are obtained from the same ores. M. Dufrenoy in his report to the Directors General of the mines of France, on the use of hot air in the Iron works of this country, states, " that the iron obtained from a furnace is generally a mixture of No. 1 and No. 2; that which first issues from the hearth is No. 1. The two sorts of pigs are known by the manner in which they flow, and above all by the disposition of the streaks which mark the surface of the metal as it cools."

In addition to No. 1 and No. 2 mentioned by M. Dufrenoy, No. 3 is frequently produced; it generally contains less carbon than No. 1 or

No. 2, and presents greater rigidiy than either of the former qualities.—From the circumstances thus stated, it will be noticed that, in comparing two irons together, it will be necessary to observe the quality, and as often as possible to compare the No. 1 of one iron with No. 1 of another iron; and in order to ensure the correct value or point of difference, this method should also be adopted in the Nos. 2 and Nos. 3.

In pursuance of these views I have endeavoured to procure the irons as much alike as possible, and to render the comparison still more perfect, I have selected the medium, or No. 2 quality, as the most suitable for the purpose. In every instance, the No. 2 iron could not be obtained, but in most cases I have kept as close to it as circumstances would admit. We may therefore, safely compare similar qualities and numbers together, either in reference to their transverse strength, or power to resist impact.

The following short summary of results may be useful in exhibiting the relative values of the No. 2, English Irons, in reference to their powers of resisting a transverse strain: their powers to resist impact and other properties

will be reserved until the close of the experiments; when an exposition of the whole will take place, and such deductions be made, as may appear indicative of the observations and trials to which they were severally subjected.

## ABSTRACT OF RESULTS FROM THE No. 2 ENGLISH IRONS.

| | | Breaking Weight. |
|---|---|---|
| Butterley, | No. 2 | 489.3 |
| Horace St. Pauls, | No. 2 | 481.9 |
| Low Moor | No. 2 | 461.6 |
| Apedale, | No. 2 | 457.0 |
| Oldberry, | No. 2 | 453.5 |
| Elsecar, | No. 2 | 446.0 |
| Lane End, | No. 2 | 444.5 |
| Adelphi, | No. 2 | 441.0 |
| Old Park, | No. 2 | 440.7 |
| Corbyn's Hall, | No. 2 | 430.7 |
| Carrol, | No. 2 | 430.3 |
| Level, | No. 2 | 418.8 |
| W. S. S. | No. 2, | 413.0 |
| Eagle Foundry, | No. 2 | 408.3 |
| Bierly, | No. 2 | 404.1 |

In the above, the breaking weights are taken from the bars, in each case reduced to exactly 1 inch square.

## No. I.
## WELSH IRONS.

Blania, No. 3, Pig Iron, Cold Blast, Monmouthshire.

| *Experiment 1st.* Depth of Bar .....1.042 Breadth do....... 1.016 Distance between supports......4ft. 6in. | | | *Experiment 2nd.* Depth of Bar...... 1.037 Breadth do....... 1.012 Distance between supports..... 4ft. 6in. | | | *Experiment 3rd.* Depth of Bar..... .1.039 Breadth do.. ..... ..1.025 Distance between supports.... .4ft. 6in. | | | *Experiment 4th.* Depth of Bar.....1.050 Breadth do ......1.019 Distance between supports .... 2ft. 3in. | | | *Experiment 5th.* Depth of bar.. ....1.014 Breadth do.. .....1.020 Distance between supports ....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed. |
| 28 | .069 | — | 28 | .070 | — | 28 | .069 | — | 112 | .032 | — | 112 | .034 | — |
| 56 | .131 | .005 | 56 | .138 | .007 | 56 | .136 | .006 | 224 | .064 | + | 224 | .068 | .003 |
| 112 | .262 | .019 | 112 | .278 | .018 | 112 | .271 | .016 | 336 | .110 | .006 | 336 | .107 | .006 |
| 168 | .413 | .036 | 168 | .442 | .032 | 168 | .438 | .037 | 448 | .134 | .008 | 448 | .151 | .008 |
| 224 | .591 | .057 | 224 | .619 | .059 | 224 | .610 | .060 | 560 | .184 | .013 | 560 | .197 | .013 |
| 280 | .770 | .090 | 280 | .809 | .091 | 280 | .801 | .097 | 672 | .229 | .020 | 672 | .247 | .020 |
| 336 | .972 | .134 | 336 | 1.032 | .147 | 336 | 1.020 | .142 | 784 | .284 | .031 | 784 | .305 | .034 |
| 392 | 1.160 | .179 | 392 | 1.276 | .208 | 392 | 1.260 | .203 | 896 | .349 | .048 | 896 | .379 | .053 |
| 448 | 1.473 | .273 | 448 | 1.582 | .302 | 448 | 1.549 | .294 | 952 | .384 | | 952 | .416 | — |
| 476 | broke | | 476 | broke | | 476 | broke | | 1008 | broke | | 1008 | broke | |
| ∴ Ultimate deflection =1.593. Broke at the centre. | | | ∴ Ultimate deflection =1.714. Broke ½ an inch from the centre. | | | ∴ Ultimate deflection =1.677. Broke ¾ of an inch from centre. | | | ∴ Ultimate deflection =.413. Broke ¼ of an inch from the centre. | | | ∴ Ultimate deflection =.448. Broke ⅜ of an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports .......... | 7159 | 14640000 | 431.5 | 1.660 | 716.2 |
| Experiment 2nd., bar 4ft. 6in. between supports.......... | | 14053000 | 437.39 | 1.777 | 777.2 |
| Experiment 3rd., bar 4ft. 6in. between supports .......... | | 14151400 | 430.1 | 1.742 | 749.2 |
| Mean............................ | 7159 | 14281466 | 432.99 | 1.726 | 747.5 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 897.2 | .4336 | 389.0 |
| Experiment 5th, bar 2ft. 3in. between supports............. | | | 961.1 | .4543 | 436.6 |
| Mean............................ | | | 929.1 | .4439 | 412.8 |

Blania, No. 3, presents an exceedingly uniform appearance. Colour a bright gray with a considerable admixture of blue.

This iron works with less freedom than the Apedale, and indicates more stiffness under the file.

## No. II.

## WELSH IRONS.

### Plaskynaston, No. 2, Pig Iron, Hot Blast.

*Experiment 1st.* Depth of Bar .....1.000; Breadth do....... .990; Distance between supports.....4ft. 6in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .080 | |
| 56 | .160 | .007 |
| 112 | .330 | .020 |
| 168 | .529 | .039 |
| 224 | .728 | .061 |
| 280 | .950 | .093 |
| 336 | 1.180 | .127 |
| 364 | broke | |

∴ Ultimate deflection =1.290. Broke ⅞ of an inch from the centre.

*Experiment 2nd.* Depth of Bar.......1.015; Breadth do........1.015; Distance between supports.....4ft. 6in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .077 | |
| 56 | .150 | .008 |
| 112 | .314 | .023 |
| 168 | .500 | .043 |
| 224 | .690 | .069 |
| 280 | .889 | .092 |
| 336 | 1.109 | .127 |
| 392 | 1.339 | .168 |

Broke ½ an inch from the centre.

*Experiment 3rd.* Depth of Bar.......1.011; Breadth do.........1.012; Distance between supports.....4ft. 6in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .078 | |
| 56 | .151 | .006 |
| 112 | .317 | .019 |
| 168 | .504 | .039 |
| 224 | .700 | .062 |
| 280 | .907 | .090 |
| 336 | 1.128 | .124 |
| 392 | 1.375 | |
| 406 | broke | |

∴ Ultimate deflection =1.433. Broke ⅜ of an inch from centre.

*Experiment 4th.* Depth of Bar......1.005; Breadth do.......1.000; Distance between supports....2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .042 | + |
| 224 | .089 | .005 |
| 336 | .145 | .010 |
| 448 | .199 | .014 |
| 560 | .258 | .020 |
| 672 | .324 | .031 |
| 728 | broke | |

∴ Ultimate deflection =.353. Broke ⅛ of an inch from the centre.

*Experiment 5th.* Depth of bar ......1.005; Breadth do........1.034; Distance between supports....2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection Load removed. |
|---|---|---|
| 112 | .040 | + |
| 224 | .081 | .005 |
| 336 | .131 | .007 |
| 448 | .184 | .010 |
| 560 | .238 | .015 |
| 672 | broke | |

∴ Ultimate deflection =.288. Broke ⅞ of an inch from the centre.

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. per square inch | Breaking weight (*b.*) | Ultimate deflection (*d.*) | Product *b* X *d* or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports | 6.916 | 13495500 | 367.7 | 1.290 | 474.3 |
| Experiment 2nd, bar 4ft. 6in. between supports | | 13229600 | 374.8 | 1.359 | 509.4 |
| Experiment 3rd, bar 4ft. 6in. between supports | | 13299800 | 392.5 | 1.449 | 568.7 |
| Mean | 6.916 | 13341633 | 378.3 | 1.366 | 517.4 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 720.8 | .3547 | 255.7 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 628.8 | .2894 | 182.0 |
| Mean | | | 674.8 | .3220 | 218.8 |

Plaskynaston Hot Blast, No. 2, is rather a weak iron, and presents an appearance technically called *kishie*, which means a clear porous fracture, emitting a brilliant light. It produces a slippery sensation under the action of the file.

# No. III.
## WELSH IRONS.
### Pant, No. 2, Pig Iron.

| *Experiment 1st.*<br>Depth of Bar.... 1.030<br>Breadth do...... 1.028<br>Distance between supports .... 4ft. 6in. | | |
|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .066 | |
| 56 | .124 | .007 |
| 112 | .266 | .018 |
| 168 | .415 | .030 |
| 224 | .567 | .048 |
| 280 | .729 | .062 |
| 336 | .896 | .082 |
| 392 | 1.074 | .106 |
| 420 | broke | |
| ∴ Ultimate deflection =1.157. Broke ¼ of an inch from the centre. | | |

| *Experiment 2nd.*<br>Depth of bar.... 1 028<br>Breadth do...... 1.026<br>Distance between supports .... 4ft. 6in. | | |
|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .062 | |
| 56 | .124 | .006 |
| 112 | .255 | .012 |
| 168 | .390 | .02 |
| 224 | .540 | .039 |
| 280 | .695 | .057 |
| 336 | .858 | .073 |
| 392 | 1.030 | .098 |
| 448 | 1.215 | .127 |
| Broke ¾ of an inch from the centre, after the weigths 448 had been replaced. | | |

| *Experiment 3rd.*<br>Depth of Bar .... 1.044<br>Breadth do....... 1.028<br>Distance between supports ....... 4ft. 6in, | | |
|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .062 | |
| 56 | .118 | + |
| 112 | .242 | .011 |
| 168 | .382 | .022 |
| 224 | .529 | .039 |
| 280 | .678 | .058 |
| 336 | .829 | .073 |
| 392 | 1.002 | .095 |
| 448 | 1.174 | .119 |
| 476 | broke | |
| ∴ Ultimate deflection =1.259. Broke ¼ an inch from the centre. | | |

| *Experiment 4th.*<br>Depth of Bar...... 1.020<br>Breadth do........ 1.022<br>Distance between supports..... 2ft. 3in. | | |
|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 112 | .030 | |
| 224 | .065 | + |
| 336 | .100 | .005 |
| 448 | .140 | .006 |
| 560 | .181 | .008 |
| 672 | .223 | .013 |
| 784 | .265 | .016 |
| 896 | .313 | .024 |
| 952 | .338 | |
| 980 | broke | |
| ∴ Ultimate deflection =.349 Broke ¾ of an inch from the centre. | | |

| *Experiment 5th.*<br>Depth of bar...... 1.039<br>Breadth do....... 1.025<br>Distance between supports .... 2ft. 3in, | | |
|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 112 | .030 | + |
| 224 | .061 | + |
| 336 | .096 | .005 |
| 448 | .134 | .006 |
| 560 | .174 | .008 |
| 672 | .212 | .011 |
| 784 | .254 | .015 |
| 896 | .296 | .021 |
| 952 | .320 | |
| 994 | broke | |
| ∴ Ultimate deflection =.336. Broke ¾ of an inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports .......... | 6.975 | 14755500 | 385.1 | 1.192 | 459.0 |
| Experiment 2nd., bar 4ft. 6in. between supports.......... | | 15512200 | 413.2 | 1.249 | 516.0 |
| Experiment 3rd., bar 4ft. 6in. between supports .......... | | 15575000 | 424.8 | 1.314 | 558.2 |
| Mean .............................. | | 15280900 | 407.7 | 1.251 | 511.0 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 921.7 | .356 | 328.1 |
| Experiment 5th, bar 2ft. 3in. between supports.............. | | | 898.3 | .3491 | 313.6 |
| Mean................................. | | | 910.0 | .3525 | 320.8 |

Pant iron is very similar in appearance to the Apedale, both in the brilliancy and compactness of its crystals when viewed with the microscope it presents rather a duller appearance round the edges, but in other respects is closely identified with that iron. It resists chipping with tenacity, but yields with greater freedom to the file.

## No. IV.
## WELSH IRONS.

### Beaufort, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st* Depth of Bar .....1.034 Breadth do....... 1.036 Distance between supports......4ft. 6in Weight of Bar 5 feet long......15lbs. 14oz. | | | *Experiment 2nd.* Depth of Bar...... 1.039 Breadth do....... 1.036 Distance between supports..... 4ft. 6in. Weight of Bar 5 feet long......16lbs. 3oz. | | | *Experiment 3rd.* Depth of Bar......1.037 Breadth do.........1.028 Distance between supports.....4ft. 6in. Weight of Bar 5 feet long......15lbs. 15oz. | | | *Experiment 4th.* Depth of Bar.....1.060 Breadth do ......1 020 Distance between supports .... 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .056 | | 28 | .055 | | 28 | .056 | | 112 | .033 | .006 |
| 56 | .116 | | 56 | .114 | | 56 | .118 | | 224 | .060 | .010 |
| 112 | .235 | .007 | 112 | .230 | .010 | 112 | .240 | .008 | 336 | .100 | .018 |
| 168 | .354 | .016 | 168 | .356 | .020 | 168 | .372 | .016 | 448 | .131 | .021 |
| 224 | .492 | .029 | 224 | .494 | .032 | 224 | .504 | .030 | 560 | .166 | .024 |
| 280 | .640 | .046 | 280 | .629 | .050 | 280 | .656 | .050 | 672 | .201 | .026 |
| 336 | .794 | .071 | 336 | .780 | .074 | 336 | .817 | .075 | 784 | .235 | .029 |
| 392 | .960 | .100 | 392 | .940 | .100 | 392 | .990 | .108 | 896 | .273 | ,034 |
| 448 | 1.140 | .129 | 448 | 1.120 | .130 | 448 | 1.180 | .148 | 1008 | .319 | .042 |
| 476 | 1.240 | | 504 | 1.140 | .178 | 504 | 1.394 | .194 | 1064 | .345 | .050 |
| 504 | broke | | 560 | 1.415 | .250 | | | | 1078 | broke | |
| | | | 588 | broke | | | | | | | |
| ∴ Ultimate deflection =1.331. Broke 1$\frac{1}{3}$ of an inch from the centre. | | | ∴ Ultimate deflection =1.651. Broke $\frac{1}{2}$ an inch from the centre. | | | When the weight 504 was replaced, it broke $\frac{1}{8}$ of an inch from the centre. | | | ∴ Ultimate deflection =.351. Broke $\frac{1}{4}$ of an inch from centre. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs. per square inch. | Breaking Weight, ($b$) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports............. | 7.122 | 16381000 | 455.0 | 1.376 | 626.0 |
| Experiment 2nd., bar 4ft. 6in. between supports............. | 7.080 | 16497000 | 525.7 | 1.715 | 901.5 |
| Experiment 3rd., bar 4ft. 6in. between supports............. | 7.122 | 16025000 | 455.9 | 1.446 | 659.2 |
| Mean............................. | 7.108 | 16301000 | 478.8 | 1.512 | 728.9 |
| Experiment 4th., bar 2ft. 3in. between supports............. | | | 940.6 | .372 | 349.9 |

## No. V.
## WELSH IRONS.
### Beaufort, No. 3, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of Bar.... 1.550 Breadth do......1.490 Distance between supports.... 4ft. 6in. Weight of Bar 5 feet long..........35¼lbs | | | *Experiment 2nd.* Depth of bar.... 1.070 Breadth do...... 1.003 Distance between supports.... 4ft. 6in Weight of Bar 5 feet long......16lbs. 2oz. | | | *Experiment 3rd.* Depth of Bar.... 1.092 Breadth do.......1.025 Distance between supports....... 4ft. 6in. Weight of Bar 5 feet long......16lbs. 7oz | | | *Experiment 4th.* Depth of Bar...... 1.048 Breadth do........1.004 Distance between supports......2ft. 3in. | | | *Experiment 5th.* Depth of bar...... 1.067 Breadth do...... 1.030 Distance between supports .... 2ft. 3in, | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection laod removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 112 | .046 | | 28 | .052 | | 28 | .050 | | 112 | .025 | | 112 | .025 | |
| 224 | .095 | + | 56 | .078 | + | 56 | .101 | + | 224 | .051 | | 224 | .051 | |
| 336 | .146 | .005 | 126 | .235 | .007 | 126 | .228 | + | 336 | .080 | | 336 | .079 | + |
| 448 | .200 | .006 | 182 | .352 | .014 | 182 | .340 | .010 | 448 | .110 | + | 448 | .107 | + |
| 560 | .256 | .009 | 238 | .476 | .027 | 238 | .458 | .021 | 560 | .143 | + | 560 | .139 | .006 |
| 672 | .315 | ·015 | 294 | .602 | .041 | 294 | .582 | .034 | 672 | .177 | .006 | 672 | .169 | .009 |
| 784 | .374 | .022 | 350 | .745 | .060 | 350 | .707 | .052 | 784 | .214 | .010 | 784 | .201 | .012 |
| 896 | .444 | .035 | 406 | .892 | .082 | 406 | .853 | .074 | 896 | .251 | .013 | 896 | .235 | .015 |
| 1008 | .508 | .046 | 462 | 1.052 | .111 | 462 | 1.006 | .101 | 1008 | .295 | .022 | 1008 | .272 | .021 |
| 1120 | .583 | .060 | 518 | 1.229 | .150 | 518 | 1.171 | .134 | 1120 | .351 | .039 | 1120 | .315 | .030 |
| 1232 | .654 | .075 | 574 | 1.432 | .209 | 574 | 1.350 | .185 | 1176 | broke | | 1232 | .363 | .045 |
| 1344 | .735 | .095 | 581 | broke | | 602 | 1.453 | .217 | | | | | | |
| 1456 | .826 | .120 | | | | 616 | broke | | | | | | | |
| 1568 | .924 | .154 | | | | | | | | | | | | |
| 1624 | .975 | | | | | | | | | | | | | |
| 1652 | broke | | | | | | | | | | | | | |
| ∴ Ultimate deflection =.999. Broke at the centre. | | | ∴ Ultimate deflection =1.458. Broke 1⅞ of an inch from the centre. | | | ∴ Ultimate deflection =1.501. Broke ⅜ of an inch from the centre. | | | ∴ Ultimate deflection =.376. Broke ¾ of an inch from the centre. | | | Broke ⅝ of an inch from the centre, after the weigth 1232 was replaced | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ........... | | | 461.5 | 1.549 | 714.8 |
| Experiment 2nd., bar 4ft. 6in. between supports........... | 7.102 | 17251000 | 506.0 | 1.560 | 789.3 |
| Experiment 3rd., bar 4ft. 6in. between supports ........... | 7.038 | 16353000 | 504.0 | 1.639 | 826.0 |
| Mean ................................ | 7.069 | 16802000 | 505.0 | 1.599 | 807.6 |
| Experiment 4th., bar 2ft. 3in. between supports ........... | | | 1067.0 | .394 | 420.4 |
| Experiment 5th, bar 2ft. 3in. between supports............ | | | 1051.0 | .387 | 406.7 |
| Mean................................ | | | 1059.0 | .390 | 413.5 |

Beaufort, No. 3, is a close fine grained Iron of great uniformity of texture, and in some degree free from a diminution of the crystals as they recede from the centre.

The colour is less sparkling and altogether duller than the Apedale; in appearance it is much akin to the Butterley.—It is a stiff working iron, obdurate to the tool, but yields more kindly to the file.

## No. VI.
## WELSH IRONS.

Maesteg, No. , Pig Iron, (Marked White,) Glamorganshire.

| *Experiment 1st.* | | | *Experiment 2nd.* | | | *Experiment 3rd.* | | | *Experiment 4th.* | | | *Experiment 5th.* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth of Bar.... 1.520<br>Breadth do......1.480<br>Distance between supports .... 4ft. 6in.<br>Weight of Bar 5 feet long.......... 35¼lbs | | | Depth of bar.... 1.047<br>Breadth do...... 1.020<br>Distance between supports .... 4ft. 6in.<br>Weight of Bar 5 feet long.......... 16lbs. | | | Depth of Bar .... 1.035<br>Breadth do.......1-035<br>Distance between supports....... 4ft. 6in,<br>Weight of Bar 5 feet long.......... 16lbs. | | | Depth of Bar...... 1.030<br>Breadth do........1.027<br>Distance between supports......2ft. 3in. | | | Depth of bar......1.038<br>Breadth do.......1.012<br>Distance between supports ....2ft. 3in. | | |
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed. |
| 56 | .026 | | 28 | .062 | | 28 | .062 | | 112 | .030 | | 112 | .031 | |
| 112 | .056 | + | 56 | .130 | + | 56 | .133 | + | 224 | .069 | + | 224 | .070 | + |
| 224 | .115 | .005 | 112 | .271 | .012 | 112 | .274 | .014 | 336 | .105 | .005 | 336 | .106 | .005 |
| 336 | .182 | .009 | 168 | .424 | .029 | 168 | .435 | .032 | 448 | .149 | .007 | 448 | .150 | .007 |
| 448 | .255 | ·017 | 224 | .605 | .053 | 224 | .619 | .060 | 560 | .195 | .014 | 560 | .199 | .011 |
| 560 | .333 | .029 | 280 | .820 | .089 | 280 | .811 | .091 | 672 | .246 | .020 | 672 | | |
| 672 | .415 | .042 | 366 | 1.019 | .131 | 336 | 1.029 | .150 | 784 | .304 | .031 | 784 | | |
| 784 | .505 | .063 | 392 | 1.259 | .190 | 392 | 1.266 | .192 | 896 | .374 | .049 | 896 | .385 | .054 |
| 896 | .605 | .082 | 448 | 1.530 | .274 | 448 | 1.540 | .275 | 952 | .414 | | 952 | .425 | |
| 1008 | .704 | .105 | 504 | 1.880 | .419 | 504 | 1.881 | .411 | 980 | broke | | 1008 | broke | |
| 1120 | .819 | .137 | | | | | | | | | | | | |
| 1232 | .945 | .179 | | | | | | | | | | | | |
| 1344 | 1.083 | .238 | | | | | | | | | | | | |
| 1400 | 1.164 | | | | | | | | | | | | | |
| 1428 | broke | | | | | | | | | | | | | |
| ∴Ultimate deflection =1.201.<br>Broke 1½ inch from the centre. | | | Broke ¾ inch from the centre after the weight 504 was re-placed. | | | Broke ¼ inch from the centre after the weight 504 was re-placed. | | | ∴ Ultimate deflection =.433.<br>Broke ½ inch from the centre. | | | ∴Ultimate deflection =.465.<br>Broke ⅛ of an inch from the centre. | | |

| Results reduced to those of bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. per square inch | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impac. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports............ | | | 417.6 | 1.825 | 762.1 |
| Experiment 2nd, bar 4ft. 6in. between supports........... | 7.038 | 13897000 | 450.8 | 1.968 | 887.2 |
| Experiment 3rd, bar 4ft. 6in. between supports........... | 7.038 | 14022000 | 454.6 | 1.947 | 885.1 |
| Mean.............................. | 7.038 | 13959500 | 452.7 | 1.957 | 886.1 |
| Experiment 4th, bar 2ft. 3in. between supports........... | | | 899.5 | .445 | 400.2 |
| Experiment 5th, bar 2ft. 3in. between supports........... | | | 924.4 | .483 | 446.4 |
| Mean.............................. | | | 911.9 | .464 | 423.3 |

## No. VII.
## WELSH IRONS.
### Maesteg, No. , Pig Iron, (Marked Red) Glamorganshire.

*Experiment 1st.* Depth of Bar .....1.500; Breadth do.......1.470; Distance between supports......4ft. 6in; Weight of Bar 5 feet long..........34lbs.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 56 | .029 | + |
| 112 | .060 | + |
| 224 | .120 | .006 |
| 336 | .190 | .012 |
| 448 | .267 | .021 |
| 560 | .352 | .033 |
| 672 | .440 | .050 |
| 784 | .536 | .070 |
| 896 | .647 | .096 |
| 1008 | .764 | .128 |
| 1120 | .890 | .169 |
| 1232 | 1.050 | .239 |
| 1344 | 1.190 | .300 |
| 1372 | broke | |

∴ Ultimate deflection =1.225. Broke $\frac{1}{2}$ inch from the centre.

*Experiment 2nd.* Depth of Bar...... 1.045; Breadth do....... 1.011; Distance between supports..... 4ft. 6in.; Weight of Bar 5 feet long.....15lbs. 14oz.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .070 | |
| 56 | .139 | + |
| 112 | .279 | + |
| 126 | .319 | .019 |
| 182 | .487 | .041 |
| 238 | .675 | .070 |
| 294 | .881 | .112 |
| 350 | 1.115 | .169 |
| 406 | 1.385 | .245 |
| 462 | 1.702 | .370 |
| 476 | broke | |

∴ Ultimate deflection =1.788. Broke $1\frac{1}{4}$ inch from the centre.

*Experiment 3rd.* Depth of Bar......1.008; Breadth do.......1.014; Distance between supports......4ft. 6in.; Weight of Bar 5 feet long......15lbs. 2oz.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .071 | |
| 56 | .147 | |
| 112 | .298 | .014 |
| 168 | .480 | .040 |
| 224 | .680 | .070 |
| 280 | .905 | .110 |
| 336 | 1.129 | .165 |
| 392 | 1.459 | .260 |
| 448 | 1.810 | .390 |
| 462 | broke | |

∴ Ultimate deflection =1.892. Broke $\frac{7}{8}$ inch from the centre.

*Experiment 4th.* Depth of Bar.....1.028; Breadth do......1.014; Distance between supports .... 2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .033 | + |
| 224 | .075 | .005 |
| 336 | .117 | .008 |
| 448 | .164 | .011 |
| 560 | .213 | .016 |
| 672 | .272 | .025 |
| 784 | .340 | .040 |
| 896 | .421 | .068 |
| 952 | broke | |

∴ Ultimate deflection =.459. Broke at the centre.

*Experiment 5th.* Depth of bar...... 1.036; Breadth do...... 1.026; Distance between supports .... 2ft. 3in,

| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
|---|---|---|
| 112 | .034 | |
| 224 | .072 | + |
| 336 | .113 | .005 |
| 448 | .160 | .010 |
| 560 | .210 | .014 |
| 672 | .261 | .025 |
| 784 | .330 | .044 |
| 896 | .404 | .066 |
| 952 | .452 | |
| 980 | broke | |

∴ Ultimate deflection =.473. Broke at the centre.

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ............ | | | 414.8 | 1.837 | 762.0 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.059 | 13697000 | 431.2 | 1.868 | 805.4 |
| Experiment 3rd., bar 4ft. 6in. between supports ............ | 7.017 | 14246000 | 448.4 | 1.907 | 855.1 |
| Mean .............................. | 7.038 | 13971500 | 439.8 | 1.887 | 830.2 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 888.4 | .472 | 419.3 |
| Experiment 5th, bar 2ft. 3in. between supports............. | | | 889.9 | .490 | 436.0 |
| Mean.............................. | | | 889.1 | .481 | 427.6 |

The relative properties of this iron are nearly the reverse of the preceding, the texture is considerably more open, accompanied with a dark blue tinge, and seems altogether a richer iron than the Beaufort; it is more porous and works softer than the Apedale; in filing it is marked by the same adhesive properties as the Low Moor.

Maesteg *(white mark*)* is similar to the Adelphi in its granulated appearance, porous in the centre, and encased by a frame of small crystals; the colour approaches to a deep grey with a more luminous appearance in the fracture than that iron. It is rather softer than the Adelphi, and files similar to the No. 3 Beaufort.

* In all probability the iron marked white is No. 2 and the red No. 1, but whether they are of hot or cold blast is uucertain.

## No. VIII.
## WELSH IRONS.
### Pontypool, No. 2, Pig Iron.

*Experiment 1st.*
Depth of Bar.... 1.510
Breadth do...... 1.480
Distance between supports .... 4ft. 6in.
Weight of Bar 5 feet long.......... 34¼lbs.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .014 | |
| 56 | .028 | |
| 112 | .060 | + |
| 224 | .128 | .010 |
| 336 | .210 | .020 |
| 448 | .277 | .031 |
| 560 | .362 | .042 |
| 672 | .449 | .060 |
| 784 | .540 | .076 |
| 896 | .636 | .096 |
| 1008 | .745 | .125 |
| 1120 | .876 | .164 |
| 1232 | 1.002 | .218 |
| 1344 | 1.160 | .284 |

After the set had been taken, and the weight (1344) placed on again, the deflection had increased from 1.160 to 1.173. The weight was left on at night, and in the morning the bar was found broken, one inch from the centre.

*Experiment 2nd.*
Depth of bar.... 1.037
Breadth do...... 1.025
Distance between supports .... 4ft. 6in.
Weight of Bar 5 feet long ........ 15¾lbs.

| Weight in lbs | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .062 | |
| 56 | .131 | .005 |
| 112 | .286 | .019 |
| 168 | .450 | .036 |
| 224 | .631 | .063 |
| 280 | .826 | .095 |
| 336 | 1.030 | .139 |
| 392 | 1.270 | .203 |
| 448 | 1.549 | .292 |
| 476 | broke | |

∴ Ultimate deflection =1,689.
After the set had been taken and the weight (448lbs) had been placed on again, the deflection had increased from 1.549 to 1.565, the bar broke at the centre.

*Experiment 3rd.*
Depth of Bar .... 1.047
Breadth do....... 1.015
Distance between supports....... 4ft. 6in
Weight of Bar 5 feet long ........ 15¾lbs.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .064 | |
| 56 | .135 | .005 |
| 112 | .296 | .021 |
| 168 | .465 | .040 |
| 224 | .652 | .067 |
| 280 | .850 | .100 |
| 336 | 1.060 | .145 |
| 392 | 1.303 | .206 |
| 448 | 1.594 | .300 |
| 476 | 1.754 | |
| 497 | broke | |

∴ Ultimate deflection =1.874.
Broke $1\frac{1}{8}$ inch from the centre.

*Experiment 4th.*
Depth of Bar...... 1.052
Breadth do........ 1.028
Distance between supports...... 2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
|---|---|---|
| 112 | .030 | |
| 224 | .062 | |
| 336 | .096 | + |
| 448 | .135 | .005 |
| 560 | .176 | .009 |
| 672 | .225 | .016 |
| 784 | .276 | .025 |
| 896 | .336 | .040 |
| 1008 | .411 | .065 |
| 1064 | broke | |

∴ Ultimate deflection =.445.
Broke $\frac{3}{4}$ inch from the centre.

*Experiment 5th.*
Depth of bar ..... 1.025
Breadth do....... 1.025
Distance between supports .... 2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection Load removed. |
|---|---|---|
| 112 | .034 | + |
| 224 | .071 | + |
| 336 | .111 | .006 |
| 448 | .159 | .010 |
| 560 | .207 | .015 |
| 672 | .263 | .025 |
| 784 | .330 | .040 |
| 896 | broke | |

∴ Ultimate deflection =.392.
Broke $\frac{3}{4}$ inch from the centre.

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking Weight, ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | | | 398.3 | 1.752 | 697.8 |
| Experiment 2nd., bar 4ft. 6in. between supports | 7.080 | 13487000 | 431.9 | 1.752 | 756.6 |
| Experiment 3rd., bar 4ft. 6in. between supports | 7.080 | 12786000 | 446.7 | 1.962 | 876.4 |
| Mean | 7.080 | 13136500 | 439.3 | 1.857 | 816.5 |
| Experiment 4th., bar 2ft. 3in. between supports | | | 935.2 | .468 | 437.7 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 832.0 | .402 | 334.4 |
| Mean | | | 883.6 | .435 | 386.0 |

There is considerable closeness and uniformity in this iron: it presents a dull blue tinge intermixed with grey, and exhibits less lustre in its crystalline parts than the Maesteg; it very much resembles that metal in its working properties, accompanied with the same adhesion to the file.

## No. IX.
## WELSH IRONS.

Varteg Hill, South Wales, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of Bar .....1.010 Breadth do....... 1.015 Distance between supports......4ft. 6in Weight of Bar 5 feet long..........15½lbs. | | | *Experiment 2nd.* Depth of Bar...... 1.025 Breadth do....... 1.002 Distance between supports..... 4ft. 6in. Weight of Bar 5 feet long.....15lbs. 14oz. | | | *Experiment 3rd.* Depth of Bar......1.029 Breadth do.. ..... ..1.031 Distance between supports......2ft. 3in. | | | *Experiment 4th.* Depth of Bar.....1.029 Breadth do ......1.025 Distance between supports ....2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection loadremoved. |
| 112 | .278 | .012 | 112 | .275 | .010 | 112 | .031 | | 112 | .032 | |
| 126 | .313 | .017 | 126 | .310 | .013 | 224 | .067 | | 224 | .068 | |
| 182 | .480 | .035 | 182 | .472 | .029 | 336 | .104 | + | 336 | .109 | + |
| 238 | .652 | .061 | 238 | .645 | .054 | 448 | .144 | .006 | 448 | .153 | .008 |
| 294 | .846 | .090 | 294 | .835 | .081 | 560 | .185 | .009 | 560 | .199 | .013 |
| 350 | 1.050 | .132 | 350 | 1.040 | .115 | 672 | .225 | .014 | 672 | .251 | .020 |
| 406 | 1.280 | .189 | 378 | 1.160 | .150 | 784 | .273 | .023 | 784 | .311 | .033 |
| 462 | 1.550 | .261 | 392 | broke | | 896 | .339 | .050 | 896 | broke | |
| 476 | 1.620 | broke | | | | 952 | .365 | | | | |
| | | | | | | 980 | broke | | | | |
| Broke at the centre. | | | ∴ Ultimate deflection =1.225. Broke ¼ of an inch from the centre. | | | ∴ Ultimate deflection =39.5. Broke at the centre. | | | ∴ Ultimate deflection =.367. Broke ¼ inch from the centre. | | |

| Results reduced to those of bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight (b.) | Ultimate deflection (d.) | Product b X d or power of resisting impac. |
| Experiment 1st, bar 4ft. 6in between supports ............ | 6.997 | 15166000 | 471.0 | 1.644 | 774.3 |
| Experiment 2nd, bar 4ft. 6in. between supports ............ | 7.017 | 14858000 | 372.3 | 1.256 | 467.6 |
| Mean ............ | 7.007 | 15012000 | 421.6 | 1.450 | 620.9 |
| Experiment 3rd, bar 2ft. 3in. between supports ............ | | | 897.7 | .406 | 364.5 |
| Experiment 4th, bar 2ft. 3in. between supports ............ | | | 825.6 | .378 | 312.0 |
| Mean ............ | — | — | 861.6 | .392 | 338.2 |

Varteg Hill is a more obdurate and dense iron than the Apedale; it is analogous to the Wind Mill End metal, but inferior to it in strength and power to resist impact.—On viewing the fracture the crystals appear close, but not so clearly developed as those in the Adelphi and Apedale.—The working of this iron is rather of a harsh and crumbling nature, and occasional slips are felt as if filing a polished surface.

## No. X.

## WELSH IRONS.

### Pentwyn, No. 2, Pig Iron.

*Experiment 1st.*
Depth of Bar ......1.012
Breadth do........1.020
Distance between supports......4ft. 6in.
Weight of Bar 5 feet long..........16lbs.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .056 | |
| 56 | .117 | + |
| 112 | .247 | .009 |
| 168 | .373 | .020 |
| 224 | .520 | .030 |
| 280 | .680 | .048 |
| 336 | .850 | .071 |
| 392 | 1.034 | .101 |
| 448 | 1.236 | .143 |
| 504 | 1.461 | .201 |

When the weight 504 was placed on again, the bar broke 1⅜ inch from the centre.

*Experiment 2nd.*
Depth of Bar ....... 1.065
Breadth do........ 1.028
Distance between supports.....4ft. 6in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .056 | |
| 56 | .116 | + |
| 112 | .238 | .008 |
| 168 | .372 | .016 |
| 224 | .510 | .030 |
| 280 | .669 | .048 |
| 336 | .838 | .076 |
| 392 | 1.011 | .102 |
| 448 | 1.207 | .136 |
| 476 | 1.310 | |
| 490 | broke | |

∴ Ultimate deflection =1.359.
Broke 1¾ of an inch from the centre.

*Experiment 3rd.*
Depth of Bar......1.010
Breadth do........1.010
Distance between supports.....2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .028 | |
| 224 | .060 | + |
| 336 | .098 | + |
| 448 | .135 | + |
| 560 | .171 | .008 |
| 672 | .215 | .011 |
| 784 | .260 | .018 |
| 896 | .308 | .025 |
| 980 | broke | |

∴ Ultimate deflection =.344.
Broke ⅜ from the centre.

*Experiment 4th.*
Depth of Bar......1.030
Breadth do.......1.020
Distance between supports.....2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .031 | |
| 224 | .069 | + |
| 336 | .106 | + |
| 448 | .140 | .005 |
| 560 | .180 | .009 |
| 672 | .222 | .017 |
| 784 | .270 | .024 |
| 896 | .322 | .035 |
| 1008 | .381 | .050 |
| 1078 | broke | |

∴ Ultimate deflection =.415.
Broke ½ inch from the centre.

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight (*b*.) | Ultimate deflection (*d*.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports | 7.038 | 15468000 | 455.0 | 1.522 | 692.5 |
| Experiment 2nd, bar 4ft. 6in. between supports | | 14918000 | 420.2 | 1.447 | 608.0 |
| Mean | | 15193000 | 437.6 | 1.484 | 650.2 |
| Experiment 3rd, bar 2ft. 3in. between supports | | | 897.1 | .358 | 321.2 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 996.2 | .427 | 425.4 |
| Mean | | | 946.6 | .392 | 373.3 |

Pentwyn Iron, No. 2, stands rather low in the scale of strength, and appears from experiments to be one of the weakest of the Welsh irons which were tried. It has a closer texture than the Apedale, a grey blue tinge, and is attended with considerable hardness underneath the file. In mixtures it might be safely used as an alloy to the softer metals.

## No. XI.
## WELSH IRONS.
### Bute, No. 1, Pig Iron, Cold Blast.

| *Experiment 1st.*<br>Depth of bar...... 1.040<br>Breadth do....... 1.026<br>Distance between supports .... 4ft. 6in,<br>Weight of Bar 5 feet long......15lbs. 14oz | | | *Experiment 2nd.*<br>Depth of bar.... 1.021<br>Breadth do...... 1.030<br>Distance between supports .... 4ft. 6in.<br>Weight of Bar 5 feet long....15lbs. 10oz. | | | *Experiment 3rd.*<br>Depth of Bar .... 1.020<br>Breadth do.......1·015<br>Distance between supports....... 4ft. 6in,<br>Weight of Bar 5 feet long ....15lbs. 10oz. | | | *Experiment 4th.*<br>Depth of Bar ...... 1.00<br>Breadth do ........1.02<br>Distance between supports......2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .161 | | 28 | .063 | | 28 | .065 | | 112 | .035 | + |
| 56 | .125 | + | 56 | .128 | + | 56 | .130 | + | 224 | .075 | + |
| 112 | .255 | .010 | 112 | .264 | .009 | 112 | .268 | .010 | 336 | .117 | + |
| 168 | .404 | .020 | 168 | .419 | .021 | 168 | .426 | .025 | 448 | .161 | .007 |
| 224 | .564 | .040 | 224 | .587 | .041 | 224 | .583 | .045 | 560 | .205 | .011 |
| 280 | .723 | .061 | 280 | .761 | .069 | 280 | .760 | .071 | 672 | .252 | .020 |
| 336 | .905 | .092 | 336 | .940 | .096 | 336 | .947 | .105 | 784 | .303 | .025 |
| 392 | 1.100 | .126 | 392 | 1.143 | .135 | 392 | 1.149 | .137 | 896 | .363 | .038 |
| 448 | 1.318 | .176 | 448 | 1.373 | .189 | 448 | 1.380 | .190 | 952 | .400 | .048 |
| 504 | 1.570 | .244 | 504 | 1.632 | .265 | 504 | 1.637 | .264 | 994 | broke | |
| 532 | 1.710 | | 525 | broke | | 532 | broke | | | | |
| 546 | broke | | | | | | | | | | |
| ∴ Ultimate deflection =1.772.<br>Broke 2 inches from the centre. | | | ∴ Ultimate deflection =1.724.<br>Broké $1\frac{3}{4}$ inch from the centre. | | | ∴ Ultimate deflection =1.659.<br>Broke 1 inch from the centre. | | | ∴ Ultimate deflection =.428.<br>Broke $\frac{1}{4}$ inch from the centre. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking Weight, (b) | Ultimate deflectiou (d) | Product b X d or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports............ | 7.059 | 14981000 | 492.0 | 1.842 | 906.2 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.059 | 15234000 | 488.9 | 1.760 | 860.4 |
| Experiment 3rd., bar 4ft. 6in. between supports............ | 7.080 | 15274000 | 503.7 | 1.692 | 852.3 |
| Mean............................ | 7.066 | 15163000 | 494.8 | 1.764 | 872.9 |
| Experiment 4th., bar 2ft. 3in. between supports............ | | | 974.5 | .428 | 417.09 |

Bute, No. 1, Cold Blast, presents the usual appearance of the larger crystals in the centre of the fracture. It is finer grained than the Apedale, but more open than the Beaufort; in its power of being worked it is much akin to the latter. Colour a bluish grey.—From its tenacity and power to resist impact, I should pronounce this an excellent metal when applied to millwork and framing, subject to heavy strains.

## No. XII.
## WELSH IRONS.
### Brimbo, No. 2, Pig Iron, Cold Blast.

*Experiment 1st.*
Depth of Bar.... 1.025
Breadth do...... 1.015
Distance between supports .... 4ft. 6in.
Weight of Bar 5 feet long...... 16lbs. 3oz.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .063 | |
| 56 | .130 | + |
| 112 | .265 | .014 |
| 168 | .423 | .030 |
| 224 | .595 | .055 |
| 280 | .079 | .084 |
| 336 | .976 | .120 |
| 392 | 1.191 | .165 |
| 448 | 1.427 | .225 |
| 476 | 1.561 | |
| 497 | broke | |

∴ Ultimate deflection =1.651.
Broke ⅜ inch from the centre.

*Experiment 2nd.*
Depth of bar...... 1.017
Breadth do....... 1.033
Distance between supports.... 4ft. 6in.
Weight of bar 5 feet long.... 15lbs. 11oz.

| Weight in lbs. | Deflection in inches. | Deflection Load removed |
|---|---|---|
| 28 | .065 | |
| 56 | .135 | + |
| 112 | .277 | .014 |
| 168 | .447 | .034 |
| 224 | .630 | .061 |
| 280 | .824 | .090 |
| 336 | 1.033 | .126 |
| 392 | 1.248 | .175 |
| 448 | 1.513 | .245 |
| 476 | 1.660 | |
| 504 | broke | |

∴ Ultimate deflection =1.788.
Broke ¾ inch from the centre.

*Experiment 3rd.*
Depth of Bar...... 1.020
Breadth do........ 1.020
Distance between supports..... 4ft. 6in.
Weight of Bar 5 feet long..... 15lbs. 14oz.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 28 | .066 | |
| 56 | .136 | .005 |
| 112 | .274 | .014 |
| 168 | .440 | .034 |
| 224 | .620 | .059 |
| 280 | .811 | .089 |
| 336 | 1.018 | .126 |
| 392 | 1.241 | .175 |
| 448 | 1.490 | .241 |
| 476 | 1.637 | |
| 490 | broke | |

∴ Ultimate deflection =1.700.
Broke at the centre.

*Experiment 4th.*
Depth of Bar..... 1.034
Breadth do...... 1.013
Distance between supports .... 2ft. 3in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .032 | + |
| 224 | .068 | + |
| 336 | .104 | + |
| 448 | .146 | .007 |
| 560 | .188 | .011 |
| 672 | .233 | .017 |
| 784 | .284 | .025 |
| 896 | .340 | .038 |
| 1008 | .405 | .059 |

Broke ⅛ of an inch from the centre after the weight had been laid on again.

*Experiment 5th.*
Depth of Bar...... 1.030
Breadth do....... 1.010
Distance between supports..... 2ft. 0in.

| Weight in lbs. | Deflection in inches. | Deflection load removed. |
|---|---|---|
| 112 | .023 | |
| 224 | .048 | + |
| 336 | .078 | + |
| 448 | .108 | + |
| 560 | .138 | .007 |
| 672 | .169 | .011 |
| 784 | .205 | .016 |
| 896 | .243 | .023 |
| 1008 | .288 | .035 |
| 1064 | .310 | |

Broke at the centre.

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product *b* x *d* or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports ............ | 7.038 | 15221000 | 466.0 | 1.692 | 788.5 |
| Experiment 2nd., bar 4ft. 6in. between supports............ | 7.017 | 14648000 | 471.7 | 1.818 | 857.5 |
| Experiment 3rd., bar 4ft. 6in. between supports ............ | 6.997 | 14866000 | 461.7 | 1.734 | 800.6 |
| Mean ............................ | 7.017 | 14911666 | 466.4 | 1.748 | 815.5 |
| Experiment 4th., bar 2ft. 3in. between supports ............ | | | 930.7 | .419 | 390.0 |
| Experiment 5th, bar 2ft. 3in. between supports, reduced from 2ft. | | | 882.7 | .403 | 355.7 |
| Mean............................ | | | 906.7 | .411 | 372.8 |

On comparing this iron with the Apedale specimen, there appears no sensible difference in colour or texture: it ranks next to Beaufort, No. 2, in the scale of strength, and is inferior only to the Ponkey, next following, in its power of resisting impact. In being worked it is very much like the Maesteg and Adelphi manufacture.

This iron may be used with safety for general purposes, and that more particularly when reduced by a slight admixture of metals of greater fluidity.

## No. XIII.
## WELSH IRONS.
### Ponkey, No. 3 Iron, Cold Blast.

| *Experiment 1st.* Depth of bar...... 1.018 Breadth do....... 1.021 Distance between supports .... 4ft. 6in, Weight of Bar 5 feet long..... 16lbs. 2oz. | | | *Experiment 2nd.* Depth of bar.... 1.024 Breadth do...... 1.024 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long...... 16lbs. 2oz. | | | *Experiment 3rd.* Depth of Bar .... 1.000 Breadth do........1·020 Distance between supports....... 4ft. 6in, Weight of Bar 5 feet long ........15¾lbs. | | | *Experiment 4th.* Depth of Bar...... 1.028 Breadth do........1.025 Distance between supports....1ft. 10in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. |
| 28 | .056 | | 28 | .056 | | 28 | .056 | | 112 | .013 | |
| 56 | .119 | + | 56 | .121 | + | 56 | .119 | + | 224 | .030 | |
| 112 | .242 | .011 | 112 | .240 | .009 | 112 | .240 | .009 | 336 | .050 | + |
| 168 | .368 | .020 | 168 | .374 | .020 | 168 | .377 | .020 | 448 | .070 | + |
| 224 | .509 | .032 | 224 | .518 | .031 | 224 | .517 | .031 | 560 | .088 | + |
| 280 | .651 | .049 | 280 | .662 | .050 | 280 | .658 | .044 | 672 | .105 | .005 |
| 336 | .801 | .069 | 336 | .812 | .069 | 336 | .809 | .065 | 784 | .124 | .006 |
| 392 | .963 | .093 | 392 | .982 | .098 | 392 | .970 | .090 | 896 | .145 | .008 |
| 448 | 1.145 | .127 | 448 | 1.161 | .130 | 448 | 1.149 | .121 | 1008 | .165 | .010 |
| 504 | 1.341 | .173 | 504 | 1.361 | .177 | 504 | 1.342 | .162 | 1120 | .191 | .014 |
| 560 | 1.560 | .235 | 560 | 1.590 | .238 | 560 | 1.565 | .226 | 1232 | .216 | .019 |
| 588 | broke | | 581 | broke | | 588 | 1.690 | | 1344 | .241 | .025 |
| | | | | | | 616 | broke | | 1456 | .272 | .034 |
| | | | | | | | | | 1568 | .310 | .049 |
| ∴ Ultimate deflection =1.664. Broke ⅝ inches from the centre. | | | ∴ Ultimate deflection =1.670. Broké 1¾ inches from the centre. | | | ∴ Ultimate deflection =1.802. Broke 3⅝ inch from the centre. | | | Broke ⅜ inch from the centre after the weight 1568 had been replaced. | | |

| Results reduced to those of bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity. | Modulus of elasticity in lbs. per square inch | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
| Experiment 1st, bar 4ft. 6in between supports | 7.164 | 16914000 | 555.7 | 1.694 | 941.3 |
| Experiment 2nd, bar 4ft. 6in. between supports | 7.080 | 16708000 | 541.1 | 1.710 | 925.3 |
| Experiment 3rd, bar 4ft. 6in. between supports | 7.122 | 18011000 | 603.9 | 1.838 | 1110.0 |
| Mean | 7.122 | 17211000 | 566.9 | 1.747 | 992.2 |
| Experiment 4th, bar 2f. 3i. between supports reduced from 1f. 10i. | | | 1180.0 | .480 | 566.4 |

Ponkey, No. 3, stands No. 1 as regards the breaking weight and the power of resisting impact: it is of a white grey colour, exceedingly close grained, of high specific gravity, and remarkable for the dense uniformity of its appearance when fractured. Notwithstanding the tenacity of this metal, it is not of a hard obdu rate character, but yields with comparative freedom to the chisel and file; it is a good mixing iron in combination with some of the more tender metals.

## No. XIV.

## WELSH IRONS.

### Frood, No. 2, Pig Iron, Cold Blast.

| *Experiment 1st.* Depth of Bar.... 1.014 Breadth do...... 1.014 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long ...... 15lbs. 7oz. | | | *Experiment 2nd.* Depth of bar...... 1.000 Breadth do.. ..... 1.012 Distance between supports .... 4ft. 6in. Weight of bar 5 feet long .... 15lbs. 6oz. | | | *Experiment 3rd.* Depth of Bar...... 1.020 Breadth do.. .... .. 1.020 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long ..... 15lbs. 6oz. | | | *Experiment 4th.* Depth of Bar..... 1.005 Breadth do ...... 1.030 Distance between supports .... 2ft. 3in. | | | *Experiment 5th.* Depth of Bar ...... 1.017 Breadth do ....... 1.020 Distance between supports..... 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .070 | | 28 | .078 | | 28 | .070 | | 112 | .038 | + | 112 | .038 | + |
| 56 | .141 | + | 56 | .151 | + | 56 | .141 | + | 224 | .075 | + | 224 | .081 | + |
| 112 | .289 | .015 | 112 | .309 | .013 | 112 | .295 | .019 | 336 | .116 | .005 | 336 | .126 | .007 |
| 168 | .459 | .032 | 168 | .481 | .024 | 168 | .470 | .039 | 448 | .160 | .009 | 448 | .175 | .014 |
| 224 | .639 | .058 | 224 | .670 | .046 | 224 | .661 | .064 | 560 | .208 | .013 | 560 | .231 | .025 |
| 280 | .829 | .089 | 280 | .881 | .079 | 280 | .860 | .098 | 672 | .260 | .019 | 672 | .292 | .038 |
| 336 | 1.049 | .128 | 336 | 1.116 | .121 | 336 | 1.099 | .144 | 784 | .318 | .030 | 784 | .355 | .055 |
| 392 | 1.282 | .178 | 392 | 1.390 | .183 | 392 | 1.350 | .202 | 896 | .381 | .046 | 840 | .400 | .069 |
| 448 | 1.558 | .250 | 448 | 1.709 | .280 | 448 | 1.650 | .289 | 952 | broke | | 868 | broke | |
| 476 | 1.718 | | 462 | broke | | 469 | broke | | | | | | | |
| 504 | broke | | | | | | | | | | | | | |
| ∴ Ultimate deflection =1.857. Broke 1/8 inch from the centre. | | | ∴ Ultimate deflection =1.783. Broke 1/8 inch from the centre. | | | ∴ Ultimate deflection =1.753. Broke 1/4 inch from the centre. | | | ∴ Ultimate deflection =.412. Broke 3/8 inch from the centre. | | | ∴ Ultimate deflection =.416. Broke 1 inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports | 7.080 | 14431000 | 483.4 | 1.883 | 910.2 |
| Experiment 2nd, bar 4ft. 6in. between supports | 7.017 | 14100000 | 456.5 | 1.804 | 823.5 |
| Experiment 3rd, bar 4ft. 6in. between supports | 6.997 | 13807000 | 441.9 | 1.788 | 790.1 |
| Mean | 7.031 | 14112666 | 460.4 | 1.825 | 841.2 |
| Experiment 4th, bar 2ft. 3in. between supports | | | 915.1 | .414 | 378.9 |
| Experiment 5th, bar 2ft. 3in. between supports | | | 822.8 | .423 | 348.0 |
| Mean | | | 868.9 | .418 | 363.4 |

Frood, Cold Blast, No. 2, presents less brilliancy, but more uniformity, than the Apedale; it is a free and rather open iron, and might be depended upon in castings exposed to vibratory motion; its power of resisting impact is next to that of the Low Moor, and its working properties are much the same as that metal.

Pursuing the same method with the Welsh as already adopted with the English Irons, we have their comparative valucs in the No. 2 qualities, as under :—

ABSTRACT OF RESULTS FROM THE
No. 2 WELSH IRONS.

| | | |
|---|---|---|
| Beaufort | No. 2 | 478.8 |
| Brimbo | No. 2 | 466.4 |
| Frood | No. 2 | 460.6 |
| Maesteg* | No. 2 | 452.7 |
| Pontypool | No. 2 | 439.3 |
| Pentwyn | No. 2 | 437.6 |
| Varteg | No. 2 | 421.6 |
| Pant | No. 2 | 407.7 |
| Plaskynaston | No. 2 | 378.3 |

The breaking weights are taken, in this and every other instance, on the bars reduced by calculation to one inch square.

* "Maesteg White Mark," is supposed to be No. 2 Iron.

## No. I.
## SCOTCH IRONS.
### Gartsherrie, Hot Blast, No. 3, Pig Iron.

| *Experiment 1st.* Depth of bar...... 1.025 Breadth do....... 1.035 Distance between supports .... 4ft. 6in Weight of Bar 5 feet long......15lbs. 10oz, | | | *Experiment 2nd.* Depth of bar.... 1 020 Breadth do...... 1.024 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long......15lbs. 8oz. | | | *Experiment 3rd.* Depth of Bar .... 1.015 Breadth do.......1.015 Distance between supports....... 4ft. 6in, Weight of Bar 5 feet long......15lbs. 7oz. | | | *Experiment 4th.* Depth of Bar...... 1.020 Breadth do........1.035 Distance between supports....2ft. 3in. | | | *Experiment 5th.* Depth of Bar .....1.015 Breadth do....... 1.022 Distance between supports......2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .067 | | 28 | .070 | | 28 | .070 | | 112 | .036 | | 112 | .035 | |
| 56 | .140 | + | 56 | .147 | + | 56 | .147 | + | 224 | .072 | + | 224 | .072 | + |
| 112 | .280 | .015 | 112 | .297 | .020 | 112 | .299 | .019 | 336 | .114 | + | 336 | .115 | .005 |
| 168 | .444 | .030 | 168 | .465 | .038 | 168 | .470 | .034 | 448 | .156 | .007 | 448 | .156 | .009 |
| 224 | .618 | .051 | 224 | .649 | .060 | 224 | .650 | .058 | 560 | .200 | .011 | 560 | .200 | .014 |
| 280 | .798 | .077 | 280 | .830 | .086 | 280 | .839 | .081 | 672 | .250 | .018 | 672 | .250 | .021 |
| 336 | 1.000 | .109 | 336 | 1.040 | .118 | 336 | 1.051 | .116 | 784 | .303 | .028 | 784 | .304 | .030 |
| 392 | 1.216 | .150 | 392 | 1.268 | .159 | 392 | 1.278 | .157 | 896 | .361 | .039 | 896 | .365 | .045 |
| 448 | 1.450 | .201 | 448 | 1.510 | .211 | 448 | 1.533 | .216 | 952 | broke | | 1008 | .430 | .060 |
| | | | 469 | broke | | | | | | | | 1036 | broke | |
| Broke ⅝ inch from the centre. | | | ∴ Ultimate deflection =1 599. Broké ½ inch from the centre. | | | Broke at the centre. | | | ∴ Ultimate deflection =.390. Broke 1¼ inch from the centre. | | | ∴ Ultimate deflection =.446. Broke ½ inch from the centre. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking Weight, ($b$) | Ultimate deflectiou ($d$) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports........... | 7.017 | 14127000 | 412.0 | 1.486 | 612.2 |
| Experiment 2nd., bar 4ft. 6in. between supports........... | | 13661000 | 440.2 | 1.631 | 718.0 |
| Experiment 3rd., bar 4ft. 6in. between supports........... | | 13894000 | 428.4 | 1.556 | 666.6 |
| Mean.............................. | 7.017 | 13894000 | 426.8 | 1.557 | 998.4 |
| Experiment 4th., bar 2ft. 3in. between supports............ | | | 884.0 | .398 | 351.8 |
| Experiment 5th, bar 2ft. 3in. between supports.............. | | | 983.9 | .456 | 448.6 |
| Mean.............................. | | | 933.9 | .427 | 400.2 |

Gartsherrie, No. 3, Hot Blast, presents an appearance similar to the Apedale, with rather more lustre; it has great uniformity in its granulated texture, like most of the Scotch Irons. Its characteristics are fluidity, accompanied with a moderate degree of softness, when submitted to the chisel and file.

I should consider this to be a useful metal when improved with an admixture of strong Welsh.

## No. II.

## SCOTCH IRONS.

### Duudaven, No. 3, Pig Iron, Cold Blast.

| *Experiment 1st.* Depth of Bar.... 1.010 Breadth do......1.018 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long...... 15lbs. 12oz | | | *Experiment 2nd.* Depth of bar......1.000 Breadth do.......1.008 Distance between supports....4ft. 6in. Weight of bar 5 feet long....15lbs. 12oz. | | | *Experiment 3rd.* Depth of Bar......1.020 Breadth do.........1.028 Distance between supports.....4ft. 6in. Weight of Bar 5 feet long.....15lbs. 11oz. | | | *Experiment 4th.* Depth of Bar.....1.015 Breadth do......1.010 Distance between supports.... 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection Load removed | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed |
| 28 | .064 | | 28 | .068 | | 28 | .069 | | 112 | .031 | |
| 56 | .128 | | 56 | .139 | | 56 | .139 | + | 224 | .070 | + |
| 112 | .252 | .006 | 112 | .272 | .010 | 112 | .240 | .008 | 336 | .105 | .003 |
| 168 | .400 | .018 | 168 | .430 | .020 | 168 | .429 | .024 | 448 | .142 | .005 |
| 224 | .550 | .031 | 224 | .597 | .039 | 224 | .590 | .041 | 560 | .180 | .008 |
| 280 | .713 | .051 | 280 | .766 | .061 | 280 | .758 | .064 | 672 | .221 | .013 |
| 336 | .889 | .080 | 336 | .959 | .092 | 336 | .948 | .096 | 784 | .265 | .020 |
| 392 | 1.079 | .111 | 392 | 1.170 | .134 | 392 | 1.148 | .132 | 840 | .289 | .024 |
| 448 | 1.290 | .162 | 448 | 1.408 | .192 | 448 | 1.377 | .188 | 896 | broke | |
| 476 | broke | | 476 | broke | | 469 | broke | | | | |
| ∴ Ultimate deflection =1.390. Broke 3 inches from the centre. | | | ∴ Ultimate deflection =1.520. Broke $\frac{3}{4}$ inch from the centre. | | | ∴ Ultimate deflection =1.457. Broke $\frac{1}{2}$ inch from the centre. | | | ∴ Ultimate deflection =.313. Broke $\frac{1}{2}$ inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight (*b.*) | Ultimate deflection (*d.*) | Product *b* X *d* or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in between supports............ | 7.101 | 16681000 | 458.3 | 1.403 | 643.0 |
| Experiment 2nd, bar 4ft. 6in. between supports............ | 7.101 | 16081000 | 472.2 | 1.520 | 717.7 |
| Experiment 3rd, bar 4ft. 6in. between supports............ | 7.059 | 16840000 | 438.5 | 1.486 | 651.6 |
| Mean.............................. | 7.087 | 16534000 | 456.3 | 1.469 | 674.1 |
| Experiment 4th, bar 2ft. 3in. between supports............. | | | 861.1 | .318 | 273.8 |

Duudaven, Cold Blast, No. 3, exhibits a duller fracture than the Gartsherrie; it however possesses the same power of being worked, besides being equally fluid, and superior in strength and power to resist impact.

## No. III.

## SCOTCH IRONS.

### Monkland, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar...... 1.020 Breadth do....... .994 Distance between supports .... 4ft. 6in. Weight of Bar 5 feet long...... 15lbs.4oz. | | | *Experiment 2nd.* Depth of bar.... 1 009 Breadth do...... 1.003 Distance between supports .... 4ft 6in. Weight of Bar 5 feet long...... 15lbs. 4oz. | | | *Experiment 3rd.* Depth of Bar .... 1.023 Breadth do....... 1·007 Distance between supports ....... 2ft. 3in, | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection, Load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 112 | .345 | .025 | 112 | .345 | .020 | 112 | .039 | |
| 126 | .390 | .030 | 126 | .390 | .025 | 224 | .081 | + |
| 182 | .598 | .053 | 182 | .599 | .050 | 336 | .127 | .005 |
| 238 | .824 | .086 | 238 | .831 | .080 | 448 | .176 | .007 |
| 294 | 1.070 | .122 | 294 | 1.080 | .115 | 560 | .230 | .011 |
| 350 | 1.352 | .179 | 350 | 1.365 | .170 | 672 | .290 | .020 |
| 406 | 1.676 | .273 | 406 | 1.710 | .274 | 784 | .357 | .031 |
| | | | 420 | broke | | 840 | broke | |
| Broke 1 inch from the centre. | | | ∴Ultimate deflection =1.800. Broké ½ inch from the centre. | | | ∴ Ultimate deflection =.389. Broke ⅜ inch from the centre. | | |

Results reduced to those of bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking Weight, (*b.*) | Ultimate deflection (*d.*) | Product $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st., bar 4ft. 6in. between supports | 6.916 | 12115000 | 392.6 | 1.709 | 671.0 |
| Experiment 2nd., bar 4ft. 6in. between supports | | 12404000 | 411.3 | 1.816 | 747.0 |
| Mean | 6.916 | 12259500 | 401.9 | 1.762 | 709.0 |
| Experiment 3rd., bar 2ft. 3in. between supports | | | 807.3 | .397 | 320.5 |

On examining the crystallization of the Monkland Iron, it presents a greater degree of richness than either the Apedale or Adelphi; it is porous in the fracture, attended with considerable brilliancy.

The Monkland is remarkable for fluidity and ease of being worked: its properties are similar in many respects to those observable in the Low Moor and Butterly metals.

Before entering on the comparative estimates of the irons of British manufacture, I would offer a few remarks on the subject generally, as also on those points which refer to the strength and other properties of the irons experimented upon. In order to ascertain their values, we must have some measure of comparison as respects their strength, fluidity, flexure, &c. I have already stated that we may safely compare one iron with another, and that comparison will hold good when made between those of the same number and quality. We must, however, be careful in contrasting the No. 1, or first description of one iron, with the No. 3 of another. As regards strength the No. 1 almost invariably exhibits greater weakness, accompanied with a greater degree of flexure than the No. 2 or No. 3. For example, the No. 1 Milton, gives 352.5 for the breaking weight, and 1.525 for flexure; whereas the No. 3 exhibits 427.4 for the breaking weight, and 1.368 for flexure. Again, the Beaufort Nos. 2 and 3 present nearly the same difference, being in the ratio of 478.8 to 505.0 as regards strength, and as 1.512 to 1.599 in the measure of ultimate deflection. On the whole, therefore, it will be found that the richer and more valuable des-

criptions of iron are, generally speaking, weaker, yet more ductile when exposed to heavy strains. They are also better adapted to those objects where the finer outlines and free working properties of the metals are required.

In forming a judgment of the quality of a particular iron, there cannot, however, be any great risk, as we have only to look into the following table of collected results, and there will be found the strength as well as the other properties of each. If, for instance, a strong compact iron was wanted, we have then to look for the number at the head of the list, and from 1 downwards to 15 will be found to partake of that character.—Again, suppose a moderately strong yet fluid iron was required, the numbers 16 down to 26 or 28, will more or less correspond with those qualifications. The same may be said of the lower numbers, all of which are a fluid and easy working class: they are admirably adapted for the finer descriptions of castings, when strength is not reqnired, and must ever be in demand where that object is not considered of importance. In all these cases, it must however be admitted, that, much depends upon using an appropriate mixture, and by judicious combina-

tion to ensure the full value, and other properties necessary to be obtained in the art of casting. With these observations a general summary of results, as obtained from the whole of the irons experimented upon, will now be exhibited.

From the above table or compendium, it appears that we have 581lbs. for the greatest strength, as obtained from the Ponkey iron; and 357lbs. for the weakest, as in the Plaskynaston: equal to 469 as a mean of the two extremes. Or, taking a general mean of the whole irons experimented upon, we have 445.6 as the average value of strength. This number is probably the nearest approach to the transverse strength of cast iron yet given to the public; it is deduced from experiments on nearly the whole of the British irons, and must, from the variety, accuracy, and number of experiments given in the preceding pages, be considered as a fair average value. Taking it therefore as the representative of the transverse strength of a rectangular bar of cast iron, 1 inch square, 4ft. 6in. between supports; and comparing it with the experiments of previous writers on the same subject, we have, instead of approximate results, considerable differences and anomalous contradictions to contend with. These differences are not exclusively applicable to the experiments now under consideration, but variable as respects the conclusions of the experimentors themselves.

Banks in his treatise "On the Power of Machines," made some few experiments on bars one inch square, but as they appear never to have been reduced to that standard, either by calculation or otherwise, we may reasonably infer, from the increase which takes place in casting from models, that they would be rather larger in size than intended, and consequently, give greater results. This seems to be the case in almost every instance where the necessary precautions are not observed, and the bars uniformly reduced to the dimensions indicated in the experiments.

Tredgold in his Essay on the Strength of Cast Iron, gives the experiments of Banks, Rondelet, Ebbels, Reynolds, &c. To these he adds some of his own; but they are not applicable for comparison with ours, as the writer had different objects in view, and never broke the bars. Those of Banks, Rondelet, Reynolds, and some well conducted experiments by Mr. Rennie, recorded by Professor Barlow, are however entitled to consideration.

Banks in four successive experiments on 1 inch square bars, 3 feet between the supports, and the weights suspended from the middle,

gives the mean breaking weight at 971.6lbs. Rondelet, according to Tredgold, presents the most anomalous results. In two experiments on bars 1.066 inches square, and 3.83 between the supports, the breaking weight is given at 482lbs. And, in four other experiments (on bars the same size and the same distance between the supports) the results are 700, 1140, 375, and 605, giving 705lbs. as the mean of the breaking weights. Again, on four other experiments, on the fractured parts of the same bars, at half the distance, or 1.915 feet between the supports, the differences are still greater, being 580, 1063, 1770 and 1360, mean 1193: or, 596.5lbs. as the breaking weight, when the bars are reduced to 3.83 feet between the supports. The great discrepancies which thus exist in Rondelet's experiments, render them unfit for the purpose of comparison with our results.

The other experiments referred to were made on bars 1 inch square, broke on supports 3 feet asunder. Their results are as follows:

| | | | |
|---|---|---|---|
| Banks from | 3 | experiments | 971.0lbs. |
| Reynolds " | 2 | " | 755.5lbs. |
| Rennie " | 2 | " | 869.0lbs. |

Now if we reduce the distance, 3 feet between the supports, to 4 feet 6 inches, we shall then have—

| | | |
|---|---|---|
| Banks | 647.7 | lbs. as the breaking weight. |
| Reynolds | 503.7 | |
| Rennie | 579.3 | |

These experiments indicate a greater degree of strength than we have been able to obtain; our strongest iron is considerably weaker than those experimented upon by Banks, and somewhat stronger than the results of Rennie indicate. Reynolds's iron approaches nearest to the mean—though it is somewhat in excess—it is rather stronger than the lower numbers, and may be considered equal to our Butterley specimens. Under all the circumstances, the differences are not great, if we except the variable results obtained by Rondelet from experiments upon the French irons. It may be presumed, too, that authors, when intending to make experiments upon a single iron, would generally choose a strong one.

In closing this research, to which I have devoted much time and attention, it is not my intention to offer any observations tending to

# GENERAL SUMMARY OF RESULTS

## GENERAL SUMMARY OF RESULTS OBTAINED FROM THE PRECEDING EXPERIMENTS ON RECTANGULAR BARS OF CAST IRON;

*Each bar being [illegible] one inch square.*

In the following abstract, the transverse strength, which may be taken as a criterion of the value of each iron, is obtained from the mean of the experiments, [illegible] 4ft. 6in. between the supports [illegible] next, on those of half the length, or 2ft. 3in. between supports. All the other [illegible] from the 4ft. 6in. bars.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 581 | 1.747 | [illegible] | Whitish gray .......... Hard |
| 2 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | [illegible] | White .......... Hard |
| 3 | [illegible] | 5 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | White .......... Hard |
| 4 | Carron, No. 3, [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Whitish gray .......... Hard |
| 5 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 517 | [illegible] | [illegible] | Dark gray .......... Hard |
| 6 | Butterley .......... | 4 | 7.038 | 15579500 | [illegible] | [illegible] | [illegible] | 1.815 | [illegible] | Dark gray .......... Soft |
| 7 | Bute, No. 1, Cold Blast .......... | 4 | 7.066 | 15163000 | [illegible] | 487 | [illegible] | 1.764 | [illegible] | Bluish gray .......... Soft |
| 8 | Wind Mill End, No. 2, Cold Blast, | 4 | 7.071 | 16490000 | 483 | 497 | [illegible] | 1.581 | [illegible] | Dark gray .......... Hard |
| 9 | Old Park, No. 2, Cold Blast .......... | 5 | 7.049 | 14607000 | 441 | 529 | [illegible] | 1.621 | 718 | Gray .......... Soft |
| 10 | Beaufort, No. 2, Hot Blast .......... | [illegible] | 7.108 | 16301000 | 478 | [illegible] | 474 | 1.512 | 729 | Dull gray .......... Hard |
| 11 | Low Moor, No. 2, Cold [illegible] | [illegible] | [illegible] | 14504500 | [illegible] | [illegible] | 472 | 1.852 | 855 | Dark Gray .......... Soft |
| 12 | [illegible], No. 1, [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | — | [illegible] | [illegible] | [illegible] | Gray .......... Rather hard |
| 13 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 453 | [illegible] | [illegible] | [illegible] | Light gray .......... Rather hard |
| 14 | [illegible], No. 2, [illegible] | 3 | 7.017 | [illegible] | 457 | 457 | [illegible] | 1.730 | 791 | Light gray .......... Soft |
| 15 | [illegible], No. 2, [illegible] | 4 | [illegible] | [illegible] | [illegible] | 457 | 455 | 1.811 | 822 | Dark gray .......... Rather Soft |
| 16 | [illegible] | 4 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Bluish gray .......... Hard |
| 17 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 455 | 451 | [illegible] | [illegible] | Dark gray .......... Rather Soft |
| 18 | [illegible], No. 1, [illegible] | 4 | 7.113 | [illegible] | [illegible] | 464 | [illegible] | 1.731 | [illegible] | Bright gray .......... Fluid |
| 19 | [illegible], No. 2, [illegible] | 5 | 7.080 | [illegible] | 441 | 457 | [illegible] | [illegible] | [illegible] | Light gray .......... Soft |
| 20 | [illegible], No. 3, [illegible] | 5 | [illegible] | [illegible] | [illegible] | 464 | [illegible] | 1.726 | 747 | Bright gray .......... Hard |
| 21 | [illegible], No. 3, Cold Blast .......... | 4 | [illegible] | [illegible] | 448 | — | 448 | [illegible] | [illegible] | Light gray .......... Hard |
| 22 | [illegible], No. 3, [illegible] | 5 | 7.017 | [illegible] | 437 | [illegible] | 447 | [illegible] | [illegible] | Light gray .......... Soft |
| 23 | Frood, No. 2, [illegible] | 5 | 7.031 | 13112666 | 460 | [illegible] | 447 | 1.825 | 841 | Light gray .......... Open |
| 24 | Lane End, No. 2 .......... | 3 | 7.028 | [illegible] | 444 | | 444 | [illegible] | [illegible] | Dark gray .......... Soft |
| 25 | Carron, No. 3, Cold Blast .......... | 5 | 7.044 | [illegible] | 444 | 443 | 443 | 1.336 | 593 | Gray .......... Soft |
| 26 | [illegible], No. 3, [illegible] | 4 | 7.087 | [illegible] | 456 | 430 | 443 | 1.469 | 674 | Dull gray .......... Rather soft. |
| 27 | [illegible] Marked Red .......... | 5 | [illegible] | [illegible] | 440 | 444 | 442 | 1.887 | 830 | Bluish gray .......... Fluid |
| 28 | [illegible], No. [illegible] | 5 | 7.007 | 13845866 | [illegible] | 454 | 442 | 1.687 | 727 | Gray .......... Soft |
| 29 | [illegible], No. 2 .......... | 5 | 7.080 | 13133500 | [illegible] | 441 | 440 | 1.857 | 810 | Dull blue .......... Rather soft |
| 30 | Wallbrook, No. 3 .......... | 5 | 6.979 | [illegible] | [illegible] | [illegible] | [illegible] | 1.443 | [illegible] | Light gray .......... Rather hard |
| 31 | Milton, No. 3, Hot Blast .......... | 4 | 7.051 | [illegible] | [illegible] | [illegible] | [illegible] | 1.368 | 587 | Gray .......... Rather hard |
| 32 | Buffery, No. 1, Hot Blast* .......... | 3 | [illegible] | [illegible] | [illegible] | | [illegible] | [illegible] | 721 | Dull gray .......... Soft |
| 33 | Level, No. 1, Hot Blast .......... | 5 | 7.080 | [illegible] | [illegible] | 403 | 432 | 1.546 | [illegible] | Light gray .......... Soft |
| 34 | Pant, No. 2 .......... | 5 | 6.975 | 15280900 | 408 | 455 | [illegible] | [illegible] | 511 | Light Gray .......... Rather hard |
| 35 | Level, No. 2, Hot Blast .......... | 6 | 7.031 | 15241000 | 419 | [illegible] | [illegible] | [illegible] | [illegible] | Dull gray .......... Soft |
| 36 | W. S. S., No. 2 .......... | 5 | 7.041 | 14953333 | 413 | 446 | [illegible] | 1.330 | [illegible] | Light gray .......... Soft |
| 37 | Eagle Foundry, No. 2, Hot Blast, | 4 | 7.038 | 14211000 | 408 | [illegible] | [illegible] | 1.512 | 618 | Bluish gray .......... Soft |
| 38 | Elsecar, No. 2, Cold Blast .......... | 4 | 6.928 | 12586500 | 446 | 408 | 427 | 2.224 | 992 | Gray .......... Soft |
| 39 | Varteg, No. 2, Hot Blast .......... | 4 | 7.007 | 15012000 | 422 | 430 | 426 | 1.150 | 621 | Gray .......... Hard |
| 40 | Coltham, No. 1, Hot Blast .......... | 5 | 7.128 | 15510066 | 464 | 385 | 424 | 1.532 | 716 | Whitish Gray .......... Rather Soft. |
| 41 | Carroll, No. 2, Cold Blast .......... | 4 | [illegible] | 17036000 | 430 | 408 | 419 | 1.231 | 530 | Gray .......... Hard |
| 42 | Muirkirk, No. 1, Hot Blast .......... | [illegible] | 6.953 | 13294400 | 417 | 419 | 418 | 1.570 | 656 | Bluish gray .......... Soft. |
| 43 | Bierley, No. 2 .......... | 5 | 7.185 | 16156133 | 404 | 432 | 418 | 1.222 | 494 | Dark gray .......... Soft |
| 44 | Coed-Talon, No. 2, Hot blast* .. | 4 | 6.969 | 14322500 | 409 | 424 | 416 | 1.882 | 771 | Bright gray .......... Soft |
| 45 | Coed-Talon, No. 2, Cold Blast* ... | 5 | 6.955 | 14304000 | 408 | 418 | 413 | 1.470 | 600 | Gray .......... Rather Soft |
| 46 | Monkland, No. 2, Hot Blast .......... | 3 | 6.916 | 12259500 | 402 | 404 | 403 | 1.762 | 709 | Bluish gray .......... Soft. |
| 47 | Ley's Works, No. 1, Hot Blast .. | 3 | 6.957 | 11539333 | 392 | — | 392 | 1.890 | 742 | Bluish gray .......... Soft |
| 48 | Milton, No. 1, Hot Blast .......... | 4 | 6.976 | 11974500 | 353 | 386 | 369 | 1.525 | 538 | Gray .......... Soft and fluid |
| 49 | Plaskynaston, No. 2, Hot Blast. .. | 5 | 6.916 | 13341633 | 378 | 337 | 357 | 1.366 | 517 | Light gray .......... Rather Soft. |

The irons with asterisks are taken from the Experiments on Hot and Cold Blast Iron, made by Mr. Hodgkinson and myself for the British Association for the Advancement of Science.—See Seventh Report, Volume VI.

† The modulus of elasticity was usually taken from the deflection caused by 112lbs. on the 4ft. 6in. bars

### RULE.

To find from the above table the breaking weight in rectangular bars, generally, calling $b$ and $d$ the breadth and depth in inches, and $l$ the distance between the supports in feet, and putting 4.5 for 4ft. 6in., we have $\frac{4.5 \times b\, d^2 S}{l}$ = breaking weight in lbs.—The value of S being taken from the table above.

For example: What weight would be necessary to break a bar of Low Moor Iron, 2 inches broad, 3 inches deep, and 6 feet between the supports? According to the rule given above, we have $b=2$ inches, $d=3$ inches, $l=6$ feet, $S=472$ from the table. Then $\frac{4.5 \times b\, d^2 S}{l} = \frac{4.5 \times 2 \times 3^2 \times 472}{6} = 6372$lbs., the breaking weight.

affect the commerce of one iron more than another. The object I had in view was entirely different: it was of a scientific nature, unaccompanied with any other consideration than that of giving, by direct experiment, a correct epitome of the chief properties of each iron, in order to determine its relative value in reference to enlarged and useful application. This has been done to the best of my ability, and, I trust, the classification thus attempted, will fully demonstrate the strength and other properties of this invaluable material. I entertain hopes that what has already been done will stimulate others to further and more successful efforts. There yet remains a wide field for experimental enquiry, and whoever enters upon it with an ardent mind and a strong desire for truth, with a determination to be at the necessary expence and trouble, having first made himself *well acquainted* with what has been done by others, will reap a rich and abundant harvest.

# REMARKS

ON

# DR. THOMSON'S PAPER

ON THE

COMBINATIONS

OF

# SULPHURIC ACID AND WATER,

BY HENRY HOUGH WATSON,

CORRESPONDING MEMBER OF THE SOCIETY.

---

Read 8th of January, 1839.

At the meeting of the British Association for the Advancement of Science, held at Bristol, in the year 1836, Dr. Thomson read a Paper entitled "*Experiments on the Combinations of Sulphuric Acid and Water.*" An abstract of the paper is published in the Report of that meeting.*

* Since I wrote this paper, I have learned that Dr. Thomson's paper is published at full length in the Fourth Volume of the "Records of General Science."

The Doctor, after telling us that the acid he made use of was pure, except that it contained $\frac{1}{5000}$th part of its weight of sulphate of lime, that it was a compound of

| | |
|---|---|
| one atom acid | 5 |
| one atom water | 1.125 |
| its atomic weight being | 6.125 |
| and that its specific gravity was | 1.8422, |

commences relating his experiments; and first alludes to the *specific gravities* of different atomic compounds of sulphuric acid and water, obtained by mixing determinate weights of the acid and water, and compares their results with the results which he obtained by calculating what the specific gravities ought to be supposing the bulk of the compound to be exactly the same as the sum of the volumes of the acid and water of which it was formed, or supposing neither condensation nor expansion to be consequent upon the combination.

He observes that the conclusion to be arrived at from this comparison of his calculation results with his experimental results, is, that the com-

pounds of one atom oil of vitriol* with one, two, and three atoms of water, have specific gravities *above* the mean, while the compounds of one atom of oil of vitriol with four, five, six, seven, eight, and nine atoms of water, have specific gravities *below* the mean. In the first case, there being a condensation, but in the second an *expansion*, and this expansion increasing with the quantity of water.

I will here give a copy of his table, from which the results mentioned are to be observed.

| Acid. Water. | Specific Gravity by Experiment. | Specific Gravity by Calculation. | Difference. |
|---|---|---|---|
| 1 atom +1 atom | 1.8422 | | |
| " +2 " | 1.7837 | 1.7114 | +0.0723 or $\frac{1}{24\frac{2}{3}}$ |
| " +3 " | 1.6588 | 1.6158 | +0.0430 or $\frac{1}{38.5}$ |
| " +4 " | 1.5593 | 1.5429 | +0.0164 or $\frac{1}{95}$ |
| " +5 " | 1.4737 | 1.4854 | —0.0117 or $\frac{1}{127}$ |
| " +6 " | 1.4170 | 1.4389 | —0.0219 or $\frac{1}{65.7}$ |
| " +7 " | 1.3730 | 1.4006 | —0.0276 or $\frac{1}{50.7}$ |
| " +8 " | 1.3417 | 1.3684 | —0.0267 or $\frac{1}{51.2}$ |
| " +9 " | 1.3105 | 1.3410 | —0.0305 or $\frac{1}{43.9}$ |
| " +10 " | 1.2845 | 1.3174 | —0.0329 or $\frac{1}{40}$ |

* This term—oil of vitriol—is used as representing the compound of one atom anhydrous acid + one atom water.

At the time he read his paper, he distributed among the persons present, printed copies of this and the other tables in his paper.

In a few days after the paper was read, Dr. Dalton (having been, as well as others who heard the paper read, surprised at the announcement of results conveying notions so very opposite to those generally entertained,) told me that on carefully looking over Dr. Thomson's printed table of specific gravities, he perceived that the author had been working according to an incorrect theorem in forming his calculation column: and such is evidently the fact. The correct rule whereby to find the mean of two specific gravities, is to divide the sum of the weights by the sum of the volumes; but this is not what Dr. Thomson has adopted:—his calculation results have been obtained by multiplying the weights severally by their specific gravities, adding the products together, and dividing the sum of those products by the sum of the weights; the quotient in which case he gives as the mean specific gravity; thus, for example, in the case of one atom acid+two atoms water,

$$\begin{array}{llll} 6.125 & \times\ 1.8422 & = & 11.2834750 \\ 1.125 & \times\ 1.0000 & = & 1.125 \\ \hline 7.250 & & & 12.4084750 \end{array}$$

12.4084750÷7.25=1.7115 mean specific gravity as given in the table.

In the same case, the example according to the *correct* rule is thus,

$$\begin{array}{llll} 6.125 & \div\ 1.8422 & = & 3.3248 \\ 1.125 & \div\ 1.0000 & = & 1.125 \\ \hline 7.250 & & & 4.4498 \end{array}$$

7.25÷4.4498=1.6292 the true mean specific gravity.

By the calculation column being corrected, the table would stand thus,

| Acid. | Water. | Sp. Gravity by Dr. Thomson's Experiment. | Specific Gravity by correct Calculation. | Difference. |
|---|---|---|---|---|
| 1 atom | +1 atom | 1.8422 | | |
| " | +2 " | 1.7837 | 1.6292 | +0.1545 |
| " | +3 " | 1.6588 | 1.5022 | +0.1566 |
| " | +4 " | 1.5593 | 1.4179 | +0.1414 |
| " | +5 " | 1.4737 | 1.3578 | +0.1159 |
| " | +6 " | 1.4170 | 1.3128 | +0.1042 |
| " | +7 " | 1.3730 | 1.2779 | +0.0951 |
| " | +8 " | 1.3417 | 1.2500 | +0.0917 |
| " | +9 " | 1.3105 | 1.2272 | +0.0833 |
| " | +10 " | 1.2845 | 1.2082 | +0.0763 |

By comparing together the two specific gravity columns, in this corrected table, we perceive that *condensation* is the consequence of dilution throughout the whole range, and that expansion is in no instance apparent. The *old* and generally *received* notion, consequently, being correct.

Having finished his remarks respecting specific gravities, he next proceeds to show the quantity of heat evolved when an atom of oil of vitriol is mixed with from one to nine atoms of water; which he determined by pouring 1000 grains of oil of vitriol, sp. gr. 1.8422, upon the requisite quantity of water, in a glass cylinder containing the water, and stirring the mixture with a thermometer. The thermometer rose with very great rapidity, and began almost immediately to descend, so that it was difficult to notice the highest point to which it rose. He gives the following table as showing the results of his experiments:

| Oil of Vitriol. | | Water. | Weight of Acid. | Weight of Water. | Thermometer rose from | Heat Evolved. |
|---|---|---|---|---|---|---|
| | | | Grains. | Grains. | | |
| 1 atom | +1 | atom | 1000 | 183.6 | 60° to 245° | 185° |
| " | +2 | " | 1000 | 367.3 | 67 to 286 | 219 |
| " | +3 | " | 1000 | 550.9 | 60 to 268 | 208 |
| " | +4 | " | 1000 | 734.6 | 60 to 263 | 203 |
| " | +5 | " | 1000 | 918.3 | 60 to 238 | 178 |
| " | +6 | " | 1000 | 1102 | 59 to 222 | 163 |
| " | +7 | " | 1000 | 1285.7 | 59 to 207 | 148 |
| " | +8 | " | 1000 | 1469.3 | 59 to 198 | 139 |
| " | +9 | " | 1000 | 1653 | 59 to 188 | 129 |

He says that when oil of vitriol previously mixed with water in atomic proportions is mixed with an atom of water, the heat evolved is much less; as appears from his following table:

| Acid. | | Water. | | Water. | Thermometer rose from | Heat Evolved. |
|---|---|---|---|---|---|---|
| [1 atom | + | 1 atom] | + | 1 atom | 60° to 245° | 185° |
| [1 " | + | 2 "] | + | 1 " | 65 to 135 | 70 |
| [1 " | + | 3 "] | + | 1 " | 64 to 110 | 46 |
| [1 " | + | 4 "] | + | 1 " | 60 to 95 | 35 |
| [1 " | + | 5 "] | + | 1 " | 63 to 76 | 13 |
| [1 " | + | 6 "] | + | 1 " | 63 to 72 | 9 |
| [1 " | + | 7 "] | + | 1 " | 63 to 70 | 7 |
| [1 " | + | 8 "] | + | 1 " | 63 to 69 | 6 |
| [1 " | + | 9 "] | + | 1 " | 63 to 67 | 4 |

He then goes on to show the specific heats of various atomic compounds of sulphuric acid and water; which he determined by putting 24 cubic inches of the acids to be tried into a flask, heating them 80° above the air of the room, and

noting the number of seconds which each took to cool 40°. The following table shows the results of his experiments.

| | | | Time of cooling 40°. |
|---|---|---|---|
| Empty Flask .. .. .. .. | | | 215.″5 |
| 24 inches of water .. .. .. | | | 5720. 7 |
| 1 atom acid | +1 | atom water | 3860. |
| " | +2 | " | 4837. 7 |
| " | +3 | " | 4587. 2 |
| " | +4 | " | 4702. 7 |
| " | +5 | " | 4831. 7 |
| " | +6 | " | 4967. 3 |
| " | +7 | " | 5075. |
| " | +8 | " | 5169. 3 |
| " | +9 | " | 5267. 7 |
| " | +10 | " | 5307. 5 |

By subtracting the 215.5 seconds (the time the empty flask took to cool) from the numbers in the preceding table, he obtained the ratios of the specific heats of equal volumes of the mixtures. And, by dividing these numbers by the specific gravities of the various liquids, as given in the first table, he obtained the specific heats of equal weights of each. His following table shows these specific heats of equal weights, that of water being unity.

| | Specific Heats. |
|---|---|
| Water .. .. ... | 1.0000 |
| 1 Acid + 1 Water | 0.3593 |
| " +2 " | 0.4707 |
| " +3 " | 0.4786 |
| " +4 " | 0.5228 |
| " +5 " | 0.5690 |
| " +6 " | 0.6091 |
| " +7 " | 0.6429 |
| " +8 " | 0.6699 |
| " +9 " | 0.7003 |
| " +10 " | 0.7201 |

He says that "to know how far these numbers accord with the theory of Dr. Irvine, at present universally admitted, viz. that the heat evolved when oil of vitriol and water are mixed is owing to the diminution of the specific heat, we must make a comparison of the specific heats above found with the specific heat of the mixture, supposing it a mean of the specific heats of the acid and water without any change;" which he does in the following table.

| | Specific Heat by Experiment | Mean Specific Heat. | Differences |
|---|---|---|---|
| Water .. .. .. | 1.0000 | | |
| Acid. Water. | | | |
| 1 atom + 1 atom | 0.3593 | | |
| " +2 " | 0.4707 | 0.4587 | +0.0120 |
| " +3 " | 0.4786 | 0.5326* | −0.0540 |
| " +4 " | 0.5228 | 0.5869 | −0.0641 |
| " +5 " | 0.5690 | 0.6306 | −0.0616 |
| " +6 " | 0.6091 | 0.6660 | −0.0569 |
| " +7 " | 0.6428 | 0.6952 | −0.0524 |
| " +8 " | 0.6699 | 0.7197 | −0.0498 |
| " +9 " | 0.7003 | 0.7405 | −0.0402 |
| " +10 " | 0.7201 | 0.7585 | −0.0384 |

* This is not exactly correct, it ought to be 0.5314.

He remarks that "the slightest comparison of the second and third columns of the table is sufficient to show that the theory of Dr. Irvine cannot be accurate. The specific heat of a compound of one atom oil of vitriol and one atom water is greater than the mean by about $\frac{1}{40}$th. Hence it is impossible that the heat evolved can be a consequence of a diminution, when no such diminution exists. In all the other compounds there is a diminution of the specific heat, but it does not correspond with the heat evolved. The greatest takes place when one atom of oil of vitriol is mixed with three atoms of water. It amounts in that case to about $\frac{1}{9}$th, and the heat evolved is 208°. But when one atom of oil of vitriol is mixed with two atoms of water, the heat evolved is 219°; yet the diminution of specific heat is only about $\frac{1}{10}$th, and consequently less than when the heat evolved is only 208°. The same want of coincidence exists in every part of the table.—Hence it follows, that when oil of vitriol and water are mixed, the heat evolved is not the consequence of a diminution of the specific heat."

To satisfy myself respecting the accuracy of

this conclusion arrived at by Dr. Thomson, I commenced a repetition of his experiments.

Having carefully prepared the different strengths of acid required, as far as that sp. gr. 1.4737=1 atom acid to 5 water; by diluting oil of vitriol sp. gr. 1.8436, (specially prepared for me by a friend, and the impurity of which I found to amount only to about the $\frac{1}{20}$th of one per cent.) with the requisite quantities of water, I found their specific heats by putting them into a glass bulb,* capable of holding about 2400 grains of water of the temperature of 60°, suspended in the centre of a room, and noting the times required for cooling from 130° to 100°, the temperature of the ambient air being exactly 56°:—the temperature of the liquid in the bulb was indicated by a thermometer, passed through the cork in the neck of the bulb, the stem of which had been marked by a file where the mercury rose to at 100° and 130°.

I found the bulb when filled with water, to require 2500 seconds for cooling; and when empty 179 seconds.

* In every case, the bulb had as much of the liquid put into it as reached up to a mark at the bottom of the neck, when the temperature of the liquid was 130°.

The following table shows the several times required for its cooling when filled with diluted acid of the different strengths.

| Anhydrous Acid. | | Water. | Specific Gravities. | Time required for cooling from 130° to 100°. |
|---|---|---|---|---|
| 1 atom | + | 2 atoms | 1.7837 | 2040 seconds. |
| 1 " | + | 3 " | 1.6588 | 2040 — |
| 1 " | + | 4 " | 1.5593 | 2055 — |
| 1 " | + | 5 " | 1.4737 | 2115 — |

By deducting 179, the number of seconds required for the cooling of the empty bulb, from the several times required for its cooling when filled with the liquids, we get the ratios of the specific heats of equal volumes of the several liquids, thus:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Water .. .. .. .. .. .. .. .. | | | | 2500 | — | 179 | = | 2321 |
| 1 atom acid | + | 2 | atoms water | 2040 | — | 179 | = | 1861 |
| 1 " | + | 3 | " | 2040 | — | 179 | = | 1861 |
| 1 " | + | 4 | " | 2055 | — | 179 | = | 1876 |
| 1 " | + | 5 | " | 2115 | — | 179 | = | 1936 |

And, dividing these numbers by the specific gravities, we get the ratios of the specific heats of equal weights, thus:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Water .. .. .. .. .. .. .. | | | | 2321 | ÷ | 1.0000 | = | 2321 |
| 1 atom acid | + | 2 | atoms water | 1861 | ÷ | 1.7837 | = | 1043.3 |
| 1 " | + | 3 | " | 1861 | ÷ | 1.6588 | = | 1121.9 |
| 1 " | + | 4 | " | 1876 | ÷ | 1.5593 | = | 1203.1 |
| 1 " | + | 5 | " | 1936 | ÷ | 1.4737 | = | 1313.7 |

Then,

| | | | | Sp. heats of equal weights, water being unity. | |
|---|---|---|---|---|---|
| 2321 | : 1043.3 | :: 1 | : | 0.4495 | 1 atom acid + 2 atoms water |
| 2321 | : 1121.9 | :: 1 | : | 0.4834 | 1 " + 3 " |
| 2321 | : 1203.1 | :: 1 | : | 0.5184 | 1 " + 4 " |
| 2321 | : 1313.7 | :: 1 | : | 0.5660 | 1 " + 5 " |

In consequence of the weather becoming much colder after I had ascertained the relative times of cooling of the articles enumerated, I was unable to make experiments upon the remaining strengths of acid which Dr. Thomson experimented upon; my desire being to make all my cooling experiments at the same atmospheric temperature. The experiments which I have been enabled to make will, however, I expect, be sufficient for the purpose for which I commenced them.

I have not myself experimentally determined the specific heat of oil of vitriol, or the liquid constituted of one atom anhydrous sulphuric acid and one water; but, assuming that the number given by Dr. Thomson is correct, the *mean* specific heats of the strengths of acid I have experimented upon, that is, the specific heats which they ought to have, as arrived at by calculation, if no diminution took place in

consequence of the dilution of oil of vitriol with water, will be the same as given by him. And, deducting my experimental specific heats from those calculated mean specific heats, we find the diminutions of specific heat resulting from the mixtures of oil of vitriol and water, thus,

| | Mean Sp. heats. | | Sp. heats by Expt. | | Diminutions of Sp. heat. |
|---|---|---|---|---|---|
| 1 atom oil of vitriol + 1 water, or 1 atom anhydrous acid + 2 water. | 0.4587 | — | 0.4495 | = | 0.0092 |
| 1 atom oil of vitriol + 2 water, or 1 atom anhydrous acid + 3 water. | 0.5314 | — | 0.4834 | = | 0.0480 |
| 1 atom oil of vitriol + 3 water, or 1 atom anhydrous acid + 4 water. | 0.5869 | — | 0.5184 | = | 0.0685 |
| 1 atom oil of vitriol + 4 water, or 1 atom anhydrous acid + 5 water. | 0.6306 | — | 0.5660 | = | 0.0646 |

Dr. Thomson, as before observed, by comparing his experimental specific heats with the mean specific heats, finds in the case of 1 atom oil of vitriol + 1 water an increase instead of a diminution of specific heat, and remarks upon the impossibility of the heat evolved being a consequence of a diminution when no diminution takes place; my experiments, on the contrary, however, show, as above, that in the same instance there is a diminution, and that it amounts to nearly $\frac{1}{50}$th; in each of the other instances they also show a diminution, the greatest being in the instance of 1 atom oil of

vitriol + 3 atoms water, in this respect corroborating the result obtained by the Doctor.

I now proceeded to investigate the heat disengaged when oil of vitriol is mixed with water in the proportions required for forming the compounds whose specific heats I had determined. Though it was indispensably requisite, in these experiments, to use the same relative proportions which Dr. Thomson used, I conceived that there must be an objection against using the same *quantity* of oil of vitriol in every experiment;—for, when 1000 grains by weight of oil of vitriol are mixed with 183.6 grains of water (1 atom oil of vitriol to 1 water), the resulting compound weighs 1183.6 grains, and, its specific gravity being 1.7837, its bulk, at the temperature of 60°, must be equal to 663.6 grains of water; and when 1000 grains of oil of vitriol are mixed with 734.6 grains of water (1 atom oil of vitriol to 4 water), the compound weighs 1734.6 grains, and, its specific gravity being 1.4737, its bulk, at the temperature of 60°, must be equal to 1177 grains of water; consequently, the bulk of the resulting mixture of 1 atom oil of vitriol with 4 water is nearly twice as great as that of 1 atom oil of

vitriol with 1 water; and the two intermediate mixtures will each have a bulk greater than the first-formed compound proportionate to the quantity of water which one contains more than the other,—the compound formed from 1 atom oil of vitriol and 2 water, will have the bulk of 824.3 grains of water, and that of 1 atom oil of vitriol and 3 water, will have the bulk of 994.6 grains of water. Though the heat given out by making the mixtures must, in every instance, be the same, when the same relative proportions of acid and water are used; yet, the indications of the thermometer immersed in the mixture must, I apprehend, be liable to some modification as the bulk of the mixture happens to be greater or less; the high temperature excited being more permanent as the bulk is greater, owing to the then less influence of the cooling agency of the surrounding atmosphere, &c.

In all my experiments on the subject, I have used such proportions of acid and water as that the resulting compounds would, at the temperature of 60°, be each of the same bulk, viz., equal to 500 grains of water.

EXPERIMENT I.

753½ grains by weight of oil of vitriol, sp. gr. 1.8436, were suddenly poured to 138.3 grains by weight of water (= 1 atom oil of vitriol + 1 water,) and well mixed with a thermometer, in a glass cup. The mercury in the thermometer rose from 50° to 234°, = an increase of 184° of temperature.

The experiment was then reversed, by pouring the water to the acid, instead of the acid to the water, in which case the mercury rose from 50° to 229°, = an increase of 179° of temperature.

EXPERIMENT II.

606.6 grains of the concentrated vitriol were poured to 222.8 grains of water (= 1 atom oil of vitriol + 2 water.) The mercury rose from 51° to 261°, = an increase of 210° of temperature.

The experiment being reversed, the mercury rose from 51° to 262°, = an increase of 211° of temperature.

EXPERIMENT III.

502.7 grains of the concentrated vitriol were poured to 276.9 grains of water(= 1 atom oil of

vitriol + 3 water.) The mercury rose from 51° to 256°, = an increase of 205° of temperature.

The experiment being reversed, the mercury rose from 51° to 258°, = an increase of 207° of temperature.

EXPERIMENT IV.

424.8 grains of the concentrated vitriol were poured to 312 grains of water (= 1 atom oil of vitriol + 4 water.) The mercury rose from 45° to 234°, = an increase of 189° of temperature.

The experiment being reversed, the mercury again rose from 45° to 234°, = an increase of 189° of temperature.

In making these experiments, care was taken that the vitriol and the water were of the same temperature as the glass in which they were to be mixed and the thermometer, all having been allowed to stand in the same situation for a considerable time. The liquid which had to be poured to the other, was poured from a bottle having a *wide* neck, in which it was weighed previously : that which was to have the other poured to it, was weighed in the cup in which the mixture was to be effected. The same vessels and

thermometer were used in every experiment. As it was impossible to pour the whole of either liquid out of the bottle, preparatory trials were, in every instance, made, previously to making the experiments, as to how much of the liquids adhered to the bottle after pouring, and as much as was thereby found to adhere, was used in addition to the quantities stated in the experiments, as a compensation.

It will be observed that in the first experiment the temperature resulting from making the mixture, was greater when the vitriol was added to the water than when the water was added to the vitriol, and that in the second and third the reverse was the case; while in the fourth there was no apparent difference. These facts must be owing to there being a greater facility of suddenly effecting the mixture in one case than another, by pouring the vitriol into the water (and then stirring,) or *vice versâ*.

The results of the experiments show that the highest temperature is produced in the same instance which Dr. Thomson found it to be produced in, viz., when one atom of oil of vitriol and two atoms of water are mixed: but, it will not be right, without further inquiry, therefrom

to adopt his conclusion. He appears, unfortunately, to have fallen into an error, in looking upon the *rise of temperature* produced as indicating the comparative number of degrees of heat evolved, which would only in reality have been the case if all the resulting mixtures had had one and the same specific heat: since each different mixture has a different specific heat, the requisite calculations must be made. The questions requiring to be answered are, How much heat will a compound formed of 1 atom oil of vitriol and 1 atom water, absorb in having its temperature raised 184°? How much will one formed of 1 atom oil of vitriol and 2 water, absorb in having its temperature raised 211°? How much will one formed of 1 atom oil of vitriol and 3 water, absorb in having its temperature raised 207°? And how much will one formed of 1 atom oil of vitriol and 4 water, absorb in having its temperature raised 189°? We cannot do better in answering these questions than use water as a standard, and determine how many degrees water would have its temperature raised by having as much heat imparted to it as would be required to raise the temperatures of the four compounds in question the number of degrees assigned to each: and, as the rise of temperature produced upon a body, by

having imparted to it a given quantity of heat, is in the inverse ratio of its specific heat, the calculations stand thus:—

*One atom Oil of Vitriol and one atom Water.*

Sp. Heat. Temp. produced.
0.4495 × 184° = 82.7. And 82.7 ÷ 1 the specific heat of water = 82°.7 the temperature which an equal weight of water would be raised by the heat required to raise the compound 184°.

*One atom Oil of Vitriol and two atoms Water.*

Sp. Heat. Temp. produced.
0.4834 × 211° = 102. And 102 ÷ 1 the specific heat of water = 102° the temperature which an equal weight of water would be raised by the heat required to raise the compound 211°.

*One atom Oil of Vitriol and three atoms Water.*

Sp. Heat. Temp. produced.
0.5184 × 207° = 107.3. And 107.3 ÷ 1 the specific heat of water = 107°.3 the temperature which an equal weight of water would be raised by the heat required to raise the compound 207°.

*One atom Oil of Vitriol and four atoms Water.*

Sp. Heat. Temp. produced.
0.5660 × 189° = 106.9. And 106.9 ÷ 1 the specific heat of water = 106°.9 the temperature

which an equal weight of water would be raised by the heat required to raise the compound 189°.

These due calculations being made, it is evident that the greatest quantity of heat *is* evolved in the instance when the greatest diminution of specific heat takes place; but, the amounts of diminution do not bear a direct ratio upon the quantities of heat evolved: yet, I think, it cannot but be concluded that the heat evolved and the rise of temperature produced, when oil of vitriol and water are mixed, are consequences of diminution of specific heat.

The circumstance of the quantities of heat evolved not being in direct proportion to the diminutions of specific heat, is opposed to the notion that the specific heats of bodies express the ratios of the total quantities of heat which bodies contain.

From the evidence furnished by my few experiments, it appears that the *differences* between the quantities of heat evolved, in the several instances, have a nearly geometrical ratio upon each other, speaking relatively to the differences between the diminutions of specific heat in the

corresponding instances;—for example, the difference between the diminution in the case of 1 atom oil of vitriol + 1 water and that in the case of 1 atom oil of vitriol + 2 water amounts to 0°.0388; and, the difference between the diminution in the case of 1 atom oil of vitriol + 2 water and that in the case of 1 atom + 3 water amounts to 0°.0205: the difference between the heat evolved when 1 atom oil of vitriol is mixed with 1 water and that evolved when 1 is mixed with 2 water amounts to as much as would raise the temperature of water 19°.3:—if the differences between the diminutions of specific heat and the differences between the quantities of heat evolved bore a direct ratio to each other, that between the heat evolved when 1 atom oil of vitriol is mixed with 2 water and when 1 is mixed with 3 water should amount to as much as would raise the temperature of water 10°.2; whereas, it only amounts to as much as would raise it 5°.3. But, to determine how far this observation may be generally applicable, a more extended series of experiments will be required; and, which, if leisure permit, I may, on some future occasion, be induced to prosecute.

Bolton-le-Moors, Dec. 24th, 1838.

# A MEMOIR

OF

# MR. EDWARD HOBSON,

AUTHOR OF

# MUSCI BRITANNICI, &c.

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BY JOHN MOORE, ESQ., F. L. S.

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Read February 19th, 1839.

An authentic history of men in humble life, resident in Manchester and the neighbourhood, who have, within the last thirty years, distinguished themselves by extraordinary acquirements in different branches of Natural History, and particularly in Botany, would be very interesting, and especially if undertaken during the life-time of some of their intelligent associates, as it would furnish many gratifying proofs of the astonishing industry and perseverance by which a fondness for science often overcomes the most disheartening difficulties.

It would also be a very valuable document, inasmuch as it would shew that many of these persons have not been more remarkable for the extent and accuracy of their knowledge, than for their quiet and inoffensive lives, and for a strict attention to those domestic duties upon which the comfort and happiness of all classes of society so much depend.

I believe it was the intention of Mr. Edwin Serjeant, had his life been spared, to have furnished the public with the most interesting particulars of Hobson's life, and, from their long intimacy, it is to be regretted that he was not able to accomplish it.

The papers and letters which he had collected for this purpose having been placed in my hands, I have been induced, as a tribute of respect to both these amiable friends, to lay before the society the following brief memoir of one of the most ardent admirers of Natural History, and accurate investigators of difficult Botany, which this country has produced.

Edward Hobson, the author of Musci Britannici, &c., was born in Ancoats Lane, Manchester,

in the year 1782, and lost his father when he was only three years old. His mother, soon after this melancholy event, having contracted habits of intemperance, he was placed by his grandfather, under the care of his uncle, William Hobson, who resided at Ashton-under-Lyne.

Here he was sent to a day school, kept by Mr. Wrigley. It is uncertain how long he remained with his uncle, but, having changed places with a younger brother, he returned to his grandfather, and was sent to school in Manchester, till he was about ten or eleven years old. In the opinion of Mr. Serjeant this was the extent of his education. It would be interesting to know what induced his first attachment to Botany.

His friend John Horsefield, of Whitefield, near Bury, one of the most intelligent of Hobson's companions, in a letter to the late John Hampson, of this town, also a very highly esteemed associate of Hobson, in answer to some inquiries on this subject, states, that "it was at the meetings of the Society of Botanists that Hobson received his earliest instruction in the science."

Horsefield also informs us that "he first met

with him at their meetings about the year 1809, and that he soon after became one of their most esteemed and useful members."

John Bentley of Staley Bridge, who published an account of new plants which he had found in the uncultivated parts of North America, was at this time one of their members.

At the same period also, George Cayley, afterwards well known as one of our most enterprising and intelligent naturalists, was an active member of the Manchester Society of Botanists, and on his return from his expedition to New South Wales in 1811, became so much attached to Hobson, that the president, John Dewhurst, complained of these friends having little time to spare for conversation with any body else.

During Cayley's appointment to superintend the Government Botanical establishment at St. Vincent's, he was a regular correspondent of Hobson, and furnished him with many rare specimens of tropical plants, and especially of ferns.

John Mellor, of Royton, and Samuel Ogden, of Middleton, appear also to have been distin-

guished members of the same society, but, in the opinion of Horsefield, "Hobson attached the highest value to the acquirements of John Dewhurst, of Manchester, who, for more than five-and-twenty years, presided over their meetings."

Being far advanced in life, Dewhurst at length resigned his situation in favour of Hobson, whose more active habits better enabled him to keep pace with the advancing knowledge of the time. By his uncommon perseverance and acuteness, Hobson was particularly fitted for the study of cryptogamic botany, and he appears to have devoted himself very early to this difficult part of the science.

Horsefield relates many instances of his daring exertions in climbing trees and rocks in pursuit of rare mosses and lichens, and describes some laughable disasters which occurred to him in his endeavours to detach curious specimens from their resting places. His favourite resorts were Cottrel clough, and Baguley moor near Altrincham, and Ashworth wood near Rochdale, whose rocks and secluded dells, Horsefield remarks, "afforded many beautiful and rare plants." But he varied his excursions in almost every direction round Manchester, and Horsefield had no doubt

"they have taken more than two hundred of these walks together, sometimes extending them to ten, twelve, and even twenty miles, but always with a determination to return home the same evening." An amusing instance of Hobson's perseverance in procuring scarce specimens is related in connexion with his old companion Crowther.

The latter having declared that he had seen an aquatic plant, which Hobson much wanted, growing in Tatton mere, near Knutsford, it was agreed that they should take the first opportunity to go there and procure it.

Hobson had great doubts as to their meeting with it, and when they came in sight of the lake, poor Crowther, whose accuracy was in question, had the mortification to find it so swollen with recent rains, that the plant was at least three feet under water.

Hobson felt for Crowther's disappointment, and set about botanizing in the adjoining fields, rather than complain of a fruitless journey.

Whilst so engaged, he heard a plunge in the water, and, looking round, Crowther had disappeared. In the greatest alarm, Hobson rushed

back, and had the satisfaction to see the old man just emerging from the water with the precious specimen in his grasp.

To a person fond of Natural History, and residing in the country, Hobson's society was invaluable. He appeared at all times quite as much gratified in communicating as in acquiring knowledge, and, from his uncommon quickness and accuracy, every walk in a garden, every field, every lane, every brook or pond afforded him opportunities of pointing out new or unobserved sources of gratification.

When taking his favourite walks, the moment he found himself clear of the smoke of Manchester his eye was upon the alert in every direction, and his countenance, at all times pleasing, assumed peculiar animation whilst he was breathing the pure air of the country.

Not many years before his death he was so kind as to accompany me on an angling excursion to Bakewell, in Derbyshire, with the view also of obtaining something like an outline of the natural history of the river Wye. He was astonished and delighted with the endless variety of water-bred flies we met with, and especially by the many

delicate specimens of the two great families Ephemeridæ and Phryganidæ, which appeared to have escaped the attention of our most careful entomologists.

A better satisfied or more bustling trio has seldom been seen on the banks of that beautiful river than myself, battling with a large and vigorous trout, an active little boy with my pannier on his back, twisting and turning his landing net in every direction to get the fish into it, and Hobson at the time in full speed after some new-born ephemera to which he was giving chase across the meadows.

During this visit we were quite satisfied that a great proportion of our Ephemeridæ and Phryganidæ are seldom seen except by anglers; and, had Hobson's life been spared, the acknowledged accuracy which he had applied so successfully to the diminutive beauties of the vegetable kingdom, would have been most willingly devoted to the splendid little insects, which, in their short lived existence, occasion to the disciples of Isaac Walton, as well as to the entomologist, an ever varying interest in the matchless scenery of the Derbyshire rivers.

The Rutland arms, at Bakewell, has long been celebrated for the excellent and liberal accommodations it has afforded to anglers, and many persons from different parts of England, when they meet together in pursuit of the delightful recreation, avail themselves of the opportunities which that county, more perhaps than any other in England, affords for the study of several branches of natural history, and especially geology and botany. I had the pleasure of introducing Hobson to some very intelligent friends there assembled, who were, as might be expected, much pleased with his conversation and manners.

It has often been remarked that the lovers of Natural History live their pleasanter days many times over. It might be truly so said of Hobson, for I believe a happier man is seldom seen than he was when engaged in arranging the insects or stretching out the mosses he had collected during his more successful rambles. With his imperfect instruction in ancient as well as modern languages, it is difficult to account for his being so well able to keep up with the new arrangements which were continually taking place in the different branches of Natural History to which he was attached, and especially with the endless

changes which occurred in descriptions of very abstruse derivation.

Whenever he was so fortunate as to find in the works of foreign authors an engraving of any insect or plant he was studying, he had a sure resource in the friendship of the very learned President of our Natural History Society, who most willingly translated the description for him, but I am not aware of any other aid which he could reckon upon.

It is gratifying to learn that amongst the companions of Hobson yet surviving, there is but one feeling as to the superiority and extent of his knowledge, and the perfect honesty and simplicity of his character. Shaw, of Bollington, thus writes of him in September, 1830,— "Hobson introduced himself to me about sixteen or eighteen years ago, by a visit to my little botanic garden, as a collector of specimens, and, from his first interview, our communications were made with that frank and open generosity which was so conspicuous in his character." Horsefield, of Whitefield, in a long and valuable communication to John Hampson, says, "Hobson was a profound practical Muscologist, and never could

have collected materials for his work had he not possessed the greatest patience and perseverance in his laborious investigations."

Horsefield informs us that "he could also number drawing amongst his various acquirements, and that he had a little book of Hobson's in his possession, containing nearly two hundred coloured drawings, exhibiting the generic and specific character of mosses, on a magnified scale, copied from a work in the College Library, which place he frequently visited during his dinner hours."

Hobson endeared himself to his associates by his frankness and generosity, and all his friends agree that he was a most affectionate husband and father, and never suffered his fondness for science to interfere with the duty of providing for the daily wants of his large family.

I have great pleasure in submitting similar and more lasting testimonials to his extraordinary acquirements, in the proofs I am enabled to furnish of the estimation in which he was held by the most celebrated botanists of his day, and especially by the distinguished authors of the

Muscologia Britannica, who have so often named him as one of their safest authorities in the more difficult articles of their celebrated work.

It does not appear that Hobson himself received much assistance from books, in the publication of his Musci Britannici, but he derived important aid from eminent botanists, who furnished him with specimens, which he could not procure in his own neighbourhood.

That he was equally liberal to others engaged in similar pursuits, will be seen by the following letter to him from Dr. Taylor, dated the 10th of Sept., 1815, in which the Doctor acknowledges the receipt of some rare and valuable plants, in the following terms :—"You will be surprised, my dear sir, at my desiring to have so many specimens of those things which you find in your neighbourhood, and which appear to me rare, but the fact is, that only thus can the science of botany be rapidly progressive, more certainly being to be learned from specimens than from the very best plates with the very best descriptions. The winter and early spring are approaching, the season for mosses, when I trust you will favour me with some specimens."

In a letter dated the 24th of March, 1816, Mr. (now Sir William) Hooker, also acknowledges the receipt of some scarce mosses from Hobson, and informs him that "he is engaged in publishing a continuation of the Flora Londinensis, with fine figures of every known species, and will be glad to receive specimens and any information respecting them which Hobson can give him."

A letter from Dr. Taylor, dated the 11th of April, 1816, is highly encouraging to Hobson, "I was much pleased" the Doctor says "with the mosses you were kind enough to send me, and if you will let me have another list of your wants, I will endeavour to supply it."

On the 3rd of February 1818, Mr. Lyell thus commences a letter to Hobson, "Dear Sir, our kind friend Mr. Hooker, has begged that I will be the channel of conveying to you his admiration of your enthusiasm and acuteness in the study of the British Mosses, and his obligations to you for your remarks, and every service in your power, by presenting you with his copy of the Muscologia, (which happened to be in my hands.) I forward it to you with great pleasure, and have endeavoured to render the present more accept-

able by the accompaniment of some Jungermanniæ and other cryptogamæ of the new Forest."

On the 8th of May, 1818, Hobson received from Dr. Hooker a letter acknowledging the receipt of the first volume of his Mosses, in the following satisfactory terms:—"My dear sir, your packet I received yesterday, and am very much obliged to you for the copy of your mosses. They are very correctly named, and got up just as I could wish them."

As this volume was illustrated with dried specimens of Mosses and Hepaticæ, instead of engravings, a few copies only could be furnished, and Hobson wrote to Mr. Scott, of Edinburgh, June 13th, 1818, to inform him that "he had received his kind order for the first volume of Mosses and Hepaticæ, with the £1. note inclosed, and that the other volume would be published as soon as sufficient materials could be collected."

Mr. Greville, the distinguished author of the Flora Edinensis, in a letter dated Wyastone, near Ashbourne, the 9th of August, 1819, thus addresses Hobson, "Dear Sir, since I had the pleasure of seeing you, I think I have been fortu-

nate enough to discover a new species of Gymnostomum. I send you the only specimen I can spare. I shall be impatient till I hear from you."

On the 7th of February, 1821, Mr. Greville "requests Hobson's assistance in procuring specimens of mosses," a list of which he sends him, and expresses himself sorry that "he cannot in return send Hobson all the specimens he wants for his second volume."

In September, 1821, Hobson complained to Dr. Hooker that he had been so confined by his business that he had not had much leisure to devote to his favourite study, yet, what time he had to spare he employed in laying down specimens for his second volume, but was certain he could not complete it without adding some of the Lichens, unless something could be done to get him the rarer species he wanted" and in the same letter he informs the Doctor that "the bearer of it, Mr. Eveleigh, of Manchester, (in whose employ Hobson then was) had a good collection of specimens of minerals as well as plants, and would convey any duplicates of rare mosses or Jungermanniæ, which the Doctor or his friends could furnish for his second volume, which he was anxious to complete as early as possible."

Hobson remained with Mr. Eveleigh from this period to the time of his death, and availed himself of the connection to acquire very considerable knowledge of mineralogy.

Those who knew Hobson will be able to estimate his feelings on the receipt of the following letter from Mr. Greville, dated the 8th of May, 1822, "My dear sir, I beg to return you my best thanks for your second volume of mosses in which I do not see any thing that requires alteration, nor will Dr. Hooker I think.

"I suppose you mean to proceed to a third volume, after you have made up your copies for the second. If you were to take in the Fungi and the Lichens you might go on for a good while, they also take much less trouble in preparing.

"Hooker thinks about a new edition of his Mus. Brit. I am working very hard at my Flora Edinensis.

Yours very truly,

R. GREVILLE."

These testimonies establish the high value of the Musci Britannici, to those who are so fortu-

nate as to possess copies of the work, and make us the more regret that Hobson had not leisure to complete the third volume here alluded to—we find him however a few years afterwards very busily engaged in the pursuit of Entomology, and Dr. Hooker, after observing he had long been in his debt, informs Hobson on the 1st of February, 1825, that having given up Entomology for ten years, he regrets he is unable to render him any assistance in that pursuit.

Jethro Tinker, a correspondent of Hobson's, residing at Staley Bridge, in the preceding year had furnished him with the names of the insects found in that neighbourhood, and requests he will pay particular attention "to the circumstance of the very few butterflies which are there to be met with."

From Hobson's correspondence with Mr. Robertson of Newcastle, Cayley, and others, it is quite clear that his attachment to botany had not been impaired by these additional pursuits. In a very long and most interesting letter from Cayley, dated Bayswater, 5th of February, 1826, he asks Hobson "if he had ever made a list of the plants growing in the neighbourhood of Manches-

ter," and tells him that "he, Cayley, had done so in 1798." From the celebrity which Cayley acquired one cannot help wishing that this list could be found. He informs Hobson that "it was not as copious in phænogamous plants as, from the general appearance of the country and the diversity of the soil, he should have expected, and that some of the most common plants in the kingdom may be reckoned amongst the scarcest near Manchester."

He also observes that "many plants have become naturalized about Manchester, which were not met with formerly, and others again have become extinct," and tells Hobson that "J. Dewhurst could give the best account on this subject, and it would be well to note down what he says upon it."

In a letter to Mr. Henry Baines, of York, dated November 6, 1827, Hobson informs him that "he had only been a short time engaged in Entomology, and could not boast much of his collection of insects.—Botany had been his favorite pursuit, at his leisure times, but that he then wished to combine them both, as it was no great additional burden to carry, and he hoped by a little diligence to do something in it."

He also mentions having sent Mr. Baines an "Entomological Nomenclature, which he had got a friend to print for him, taken from Samouelle's compendium, with a few additions, which may be useful to him for cutting up to put to his collection, or may answer as a memorandum book to know what he had got."

On the 27th of November, of the same year, Hobson writes to Cayley, to inform him that "in consequence of the extension of buildings round Manchester, many of their favorite resorts were so altered as scarcely to be known, and that he had not been able to find a single specimen of a plant which Cayley wished him to send from Scarweal Clough, seven or eight houses having been built upon the top of the bank, and the clough cut up into gardens."

On the 12th May, 1828, Hobson received an invitation to preside at the annual dinner of the Bury Botanical Society.

In a letter from Cayley, of the 26th December, 1828, he asks Hobson "if he had ever attended to the varieties of the blackberry, and mentions Baguley moor, Sale moor, Ashton moss,

and Sinderland moss, as places where two very distinct species may be found, differing both in the form of the flowers and the colour and shape of the fruit."

On the establishment of the Banksian Society in Manchester, Hobson was elected its President, which situation he held to the time of his death.

In the year 1829, having greatly distinguished himself in assisting to arrange the museum of the Manchester Society for the promotion of Natural History, it was unanimously resolved to offer him a permanent engagement in that institution, and Mr. Blackwall and myself were deputed by the Society to wait upon him for that purpose. Knowing his fondness for such pursuits, we had no doubt that the situation, with a salary of £100. per annum, would be exactly what he would desire. His reply to the offer I must endeavour to give in his own words. Having recovered himself a little from feelings which evidently overpowered him, he said,—"Gentlemen, I am deeply sensible of the great compliment and the kind attention paid to me by the offer you have made. The situation, and the salary proposed, would have been every thing I could have

wished for, but my present employer was very kind to me in his prosperity, and in his altered circumstances, as I have reason to believe my services are of more importance to him, I cannot think of leaving him."

In the spring of 1830, a bad cough, with other unfavourable symptoms, led Hobson's acquaintance to fear that his life was in great danger, and, under the direction of his kind friends Dr. Holme, Mr. Ainsworth, and others, he was induced to retire to Bowden, where comfortable lodgings had been provided for him. It was only necessary to make known to the respectable families in that neighbourhood that this amiable and interesting individual was sojourning near them in search of health, to secure for him every comfort which they had it in their power to furnish.

The last interview which the writer of this very imperfect memoir had with him, can never be forgotten. His appearance indicated the near approach of death; and his countenance, always bespeaking benevolence to others, became expressive of the deepest gratitude, whilst he pointed out the rare fruits and delicacies which had been

sent to him by persons unknown. His perfect simplicity made him quite unable to account for such seasonable attention to a stranger. I promised that I would seek out his benefactors and thank them for him.

Hobson died at Bowden on the 7th September, 1830, and was buried at St. George's Church, Hulme, where a mural tablet has been placed to his memory by his friends, with the following inscription, written by Edwin Serjeant, Esq.

"SACRED TO THE MEMORY

OF

**Edward Hobson,**

OF

MANCHESTER.

Obiit 7th September, 1830. Ætat 48.

"Humble parentage had afforded him only a scanty education—the necessary support of a numerous family demanded his daily labour.

"Yet amidst privations and difficulties, he had, by assiduity and zeal, rendered himself a most skilful Naturalist, as his scientific works and ample collections lastingly testify.

"Entomology, Botany, and Mineralogy were his favourite studies: in these many celebrated men, publicly in their writings and privately in correspondence with him, have acknowledged his great attainments.

"Such distinctions did not affect his
Natural simplicity of manners;
His character was wholly amiable."

The following letter from Sir William Hooker to Hampson, written very soon after Hobson's death, so exactly accords with the feelings of those of his friends who were best able to estimate his character and acquirements, that I am sure I shall be excused for giving it at length.

"Glasgow, Oct. 2nd, 1830.

"Sir,—I was much concerned and surprised to learn by your letter of the 11th of last month, and by the copy of the Manchester Guardian which you had the goodness to send to me, that your friend and my valued correspondent, Mr. Hobson, had died. I was not even aware that he had been in an indifferent state. His loss will be severely felt by the lovers of British Botany generally, for I hope that had he lived it was his intention to have continued his Musci Britannici, or rather to have extended the plan so as to have included the whole of the British Cryptogamæ.

"I should be happy were it in my power to have furnished you with particulars relative to his general botanical knowledge and acquirements, but unfortunately nearly all I do know of him is

by correspondence and his modesty was such that he seemed to shun making anything like a display of his abilities, and of the extent of his acquirements, and it was only incidentally that I discovered that he paid any attention to phænogamous plants. Such was his acuteness however, and so completely had he mastered all the difficulties that attend the study of Cryptogamic plants, that it was easy to perceive the phænogamous tribes would have been comprehended by him with great facility.

"It is however as a Muscologist that Mr. Hobson's name will rank in the annals of Botany. I do not know any naturalist who searched for mosses more successfully than he has done, in their native stations; nor one who discriminated them more accurately.

"His publication of 'Specimens of British Mosses and Hepaticæ' will be a lasting testimony to his correctness and deep research into their beautiful families; and in this country he has been the first to set the example of giving to the world volumes which are devoted to the illustration of entire genera of cryptogamic plants, by beautifully preserved specimens them-

selves. This method has been pursued by Mr. Drummond in his 'Mosses of Scotland,' and in his inestimable work of the 'American Mosses.'

"Once, and only once, I had the pleasure of a personal interview with Mr. Hobson. It is sixteen years ago. He came to me at the Inn, in Manchester, bringing with him many of his new discoveries, and I scarcely knew which most to admire in him, his accurate knowledge of every plant he had investigated, or the extreme diffidence and modesty he displayed in communicating that knowledge. He had then in the examination of mosses only a common pocket lens to make use of; and I had the satisfaction of giving him my Ellis' aquatic microscope by Jones, which had been my companion for many years, and which was the very last I ever employed.

"I have every reason to believe that this instrument opened to him new wonders in the vegetable creation, and contributed not a little to his very accurate knowledge of the minute cryptogamic vegetables.

"If you propose raising a subscription in the Botanical and Horticultural Society of Manches-

ter, with the view of purchasing Mr. Hobson's collection of plants, for the use of that society, I shall be happy if you will set my name down for £5. and if you will let me know when the purchase is made, I will immediately remit the money. I am, sir, your obedient servant,

W. J. Hooker."

"Mr. John Hampson, Manchester."

The Herbarium of Hobson is secured to the gardens of the Manchester Botanical and Horticultural Society. The manuscript of his "Musci Britannici" is a precious deposit in the library, and his Insects form a part of the valuable museum of the Manchester Mechanics' Institution, in the welfare of both which societies he felt a very warm interest, and the usefulness and importance of which, his own privations enabled him properly to estimate.

I have reason to believe that the highest wages Hobson ever received, were not more than forty shillings per week; and, that for many years they did not reach half that sum, yet he always kept himself out of debt; and, by the innocence of his habits and pursuits, secured to himself a portion of real happiness, which is not often exceeded.

In his anxious exertions to support his large family, he afforded a most valuable example of integrity, punctuality, and diligence in the service of his employers, and made himself many friends.

He had very early in life satisfied himself, that in no way could he so agreeably or so safely recruit himself after labour, as in the quiet study of Natural History; and this impression, added to his fondness for the science, occasioned a degree of perseverance which has seldom been equalled.

The intricate and delicate investigations he was constantly carrying on, afforded him most delightful proofs of the perfect benevolence, as well as wisdom of the Deity, and, no doubt, contributed very much to that placid benignity of character which so eminently distinguished this amiable man.

By his surviving friends Hobson's memory is warmly cherished, and they have additional satisfaction in the assura ce that it is embalmed for future times, not only in his own beautiful work, but in the writings of some of the most distinguished Botanists which this country has produced. With an enlightened community, such as that by which we are surrounded, it was impossible that

Hobson's example should be lost; and many proofs might be furnished of the excellent effect it has already had in leading others, similiarly circumstanced, to seek for relaxation and enjoyment in the same inexhaustible resources. We may, therefore, fairly hope, that the day is not far distant, when this great Metropolis of Commerce will not be more distinguished for the opportunities it holds out, to all classes, for advancement in knowledge and virtue, than for the number of its inhabitants, that, availing themselves of these inestimable privileges, afford to the world, in the superiority of their characters and acquirements, the most encouraging proofs of the value of these institutions to the comfort and happiness of society.

# CYCLOPIAN, PELASGIC, AND ETRUSCAN REMAINS,

OR

REMARKS ON THE

# MURAL ARCHITECTURE

OF REMOTE AGES.

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By WILLIAM RATHBONE GREG, Esq.

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(Read February 20, 1838.)

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"There is given
Unto the things of earth, which time hath bent,
A spirit's feeling;—and where he hath leant
His hand, but *broke his scythe*, there is a power
And magic in the ruined battlement,
For which the palace of the present hour
Must yield its pomp, and wait till ages are its dower."

*Childe Harold IV.*

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There are two kinds of topics for research;—that which, though it has the past for its subject, has the future for its object and its end; and that which relates to so remote and dim a portion of the past, that it cannot, by any possibility, be

brought to bear upon the interests of the present hour. Investigations of the first class are practical and useful;—those of the second are purely speculative, and are interesting only from the halo which antiquity throws over them, and the associations with which poetry invests them. The former are perhaps more generally and justly the favourites in this hall; but surely the latter ought not to be too peremptorily excluded; nor ought their votaries to acquiesce in such exclusion.

In asking your attention to a few condensed remarks on the most ancient ruins which exist in Europe, it must not be supposed that I am presumptuous enough to hope that I can throw much new light upon a subject which almost every successive inquirer has rendered darker than before;—a misfortune which is common to many archæological investigations, where each additional scrap of information which is raked up from the archives of antiquity overthrows an old theory, without sufficing to establish a new one on its ruins. But, as I found that many of these writers had never seen a Pelasgic fortress, and took their information on the faith of others, and, that most of the travellers who described them had seen those of Greece, or those of Italy, *exclusively*,

and, often fell into the strangest errors regarding those which they had *not* seen; and as I had visited many of every description, and in both countries, I thought I might be able to point out some considerations which have escaped previous observers, and to put in a succinct form the sum of our knowledge, or rather of our ignorance, regarding these extraordinary structures.

But even if I can impart no great novelty of information or of conjecture, yet the subject can not fail to afford, to myself at least, much pleasure. For these strange and picturesque fortifications have always been objects of the deepest interest and curiosity. Their enormous massiveness—the wild and remote situations in which they generally stand—the dim and misty antiquity of their aspect—the impenetrable obscurity which veils their history—and the conviction, that they were erected by the remote *forefathers* of a race whom we are accustomed to call, *par excellence*, the ancients, have all combined to give a beauty to their grandeur, a brightness to their desolation, and an interest to the least tidings respecting them, which the later and lovelier structures of Greece and Rome could never command.

The traveller in Greece and Italy, especially if he deviates from the regular high-road of tourists, constantly meets with fragments of massive walls, bearing upon them marks of very high antiquity, and distinguished from all other specimens of architecture, by the immense size of their materials, the peculiarity of their construction, and the entire absence of cement.

On closer examination, and more careful comparison, these ancient ruins may be generally distinguished as belonging to *three* distinct styles.

I.—The first, (of which *Lycosura*, *Tyrins*, and part of *Mycenæ*, in the *Morea*, afford the only examples extant,) is that in which the walls are composed of immense *amorphous* blocks of *unhewn* stone, laid one upon another, and having the interstices filled up with stones of a smaller size.—This is generally termed the *Cyclopian* style.*

II.—The second style, which is much more elaborate, more peculiar, and more widely spread, comprises those walls which are formed of huge *polygonal* stones, or rather pieces of rock, (gene-

* See Drawing I.

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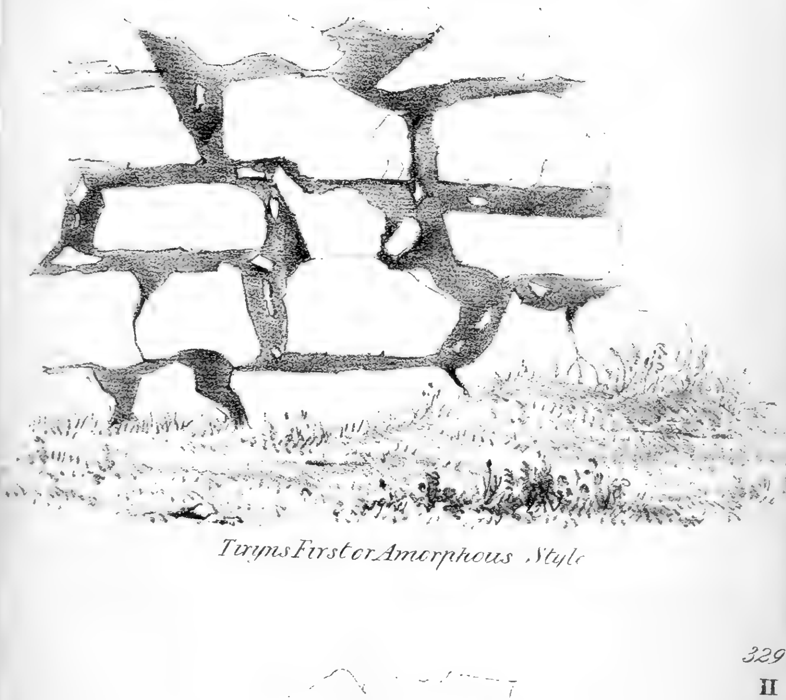
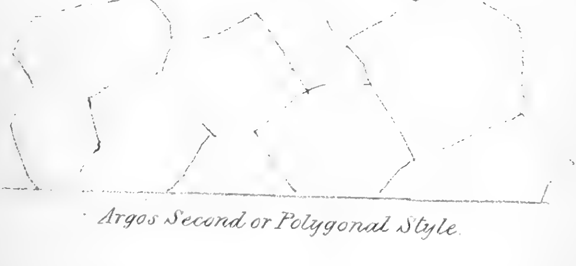
I

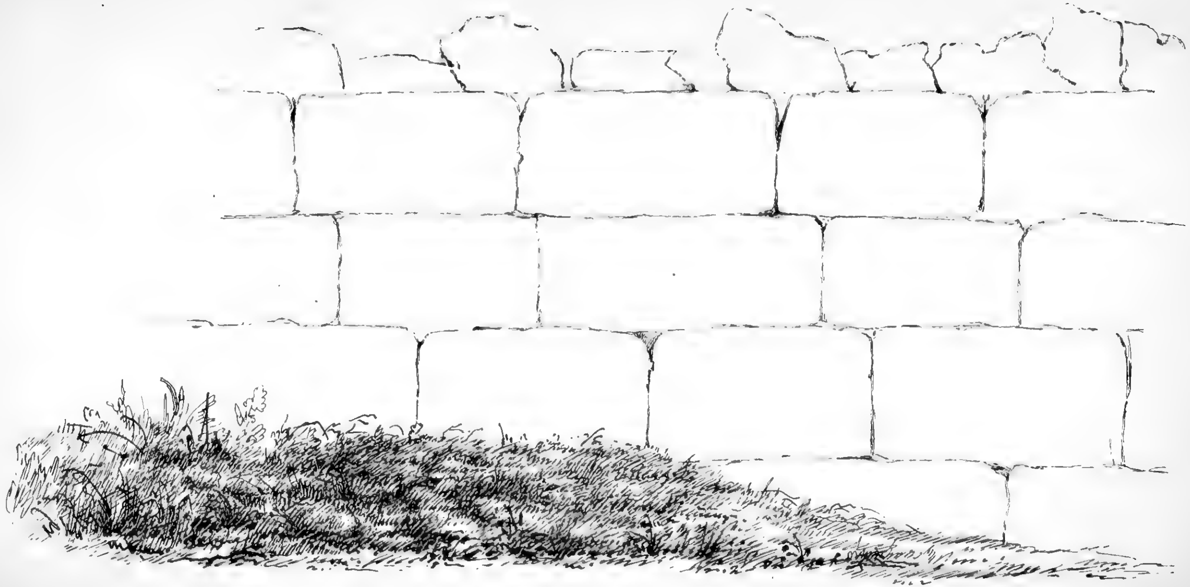


Tiryns First or Amorphous Style

329
II



Argos Second or Polygonal Style.



Cortona; Third or Etruscan Style.

rally pentagons or hexagons more or less regular) so carefully hewn and fitted to each other, as to form, externally, a perfectly smooth surface.—These are now commonly called *Pelasgic*, and may be seen in their greatest perfection, in particular portions of the walls at *Gortys* and *Mycenæ*, in Greece; and at *Norba*, *Segni*, *Cora*, *Alatri*, and various other ancient situations in Italy.

III. The third style is distinguished by the blocks of which it is composed being mostly parallelopipeds, or regular cubes, and being arranged in horizontal courses, which is rarely the case either in the amorphous or the polygonal constructions. This style is termed *Etruscan*, and is chiefly to be met with in the ancient *Etruria*, viz. at *Volterra*, *Fiesole*, *Cortona*, and many other places between the *Arno* and the *Tiber*.

Two questions now arise:

I. Are these styles really so separate and distinct that we must attribute them to different nations, or different ages?

II. To whom are they to be attributed, and why have they received their present names?

Both questions are difficult and perhaps impossible to decide.

I. The principle of the three styles seems to me essentially distinct, and is, I think, generally allowed to be so; but some writers conceive at least two of them, and perhaps all three, to be simply different methods, employed by the same people, or the same age, for particular purposes, or according to the dictates of caprice, or the skill of the individual architect. "For," they argue "the walls of *Mycenæ* afford specimens of all the three styles, though undoubtedly the polygonal predominates.* At *Cossa*, on the *Adriatic*, the lower part of the walls is polygonal, while the upper is arranged in horizontal courses;† and the *Treasury* of *Atreus*, at *Mycenæ*, exhibits a far more perfect specimen of parallel courses of hewn stone, than any of the *Etruscan* cities can furnish.‡"

* Dodwell's Cyclopian Remains. Folio, p. 5, 6. Plate V. VI. VII.

Entertaining Knowledge. Pompeii. I. p. 58.

† *Micali.* Italia avanti il dominio dei Romani. Atlas. p. 6, Plate X.

‡ Colonel Leake's Travels in the Morea. II. 373.

Pausanias Corinthiaca. II. c. 16.

Dodwell's Cyclop. Rem. Fol. p. 7, pl. X.

*Walls of Cossa.*

To this I reply, that I am disposed to believe the walls of Mycenæ to have been the work of different periods, as we know to have been the case at *Cossa*;* and *Dodwell* and *Leake*, the most accurate of travellers, confirm this opinion.† It is also very possible that by some accident the polygonal style had, in one or two parts, merged in the horizontal, from the circumstance of the builders having had a number of rectangular blocks at hand, or because they wished the main entrance to be more regularly finished than other portions, since it is chiefly near the *Gate of Lions* that the horizontal style is observable.

The perfectly regular architecture of the *Treasury* of *Atreus*, remarkable as it undoubtedly is, is wholly irrelevant to the matter, as we have no grounds whatever for believing that it was coeval with the city walls; for *Strabo*‡ tells us that *Tyrins* was founded by *Prœtus*, whose reign Blair places about 1380 B. C.; and *Pausanias*§ tells us that tradition unanimously assigned the

* Ent. Know. I. 64.

† Dodwell. Fol. p. 6.
Leake, II. 368.

‡ Book viii. p. 540. Fol. ed: Clarendon Press, 1787.

§ Pausanias, Book ii. c. 15.
Strabo, viii. p. 547.

foundation of *Mycenæ* to *Perseus*, whom some call the brother, and others the nephew, of Prœtus, in which cases its origin may be referred to nearly the same date*. Now we have no ground whatever for believing that the subterranean building, called by some the *Treasury* of *Atreus*, and by others the *Tomb* of Agamemnon, was erected till the *War of Troy*, when that prince reigned over the city—an event which is generally placed about B. C. 900.† Thus it would appear that the Treasury was not built till nearly five centuries after the foundation of the walls, and it may, therefore, be considered rather as Hellenic than as Cyclopian.

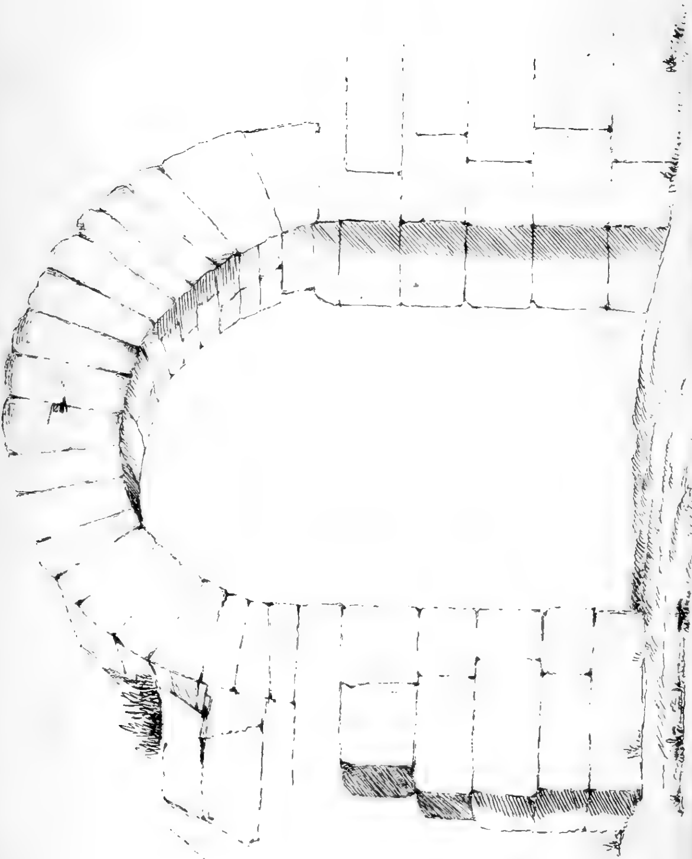
The difference between the first and second styles is sufficiently marked by the one consisting of unhewn and amorphous masses; and the other of hewn and well compacted polygons; and that both these are referable to an age anterior to that which produced the third or horizontal style, may I think, be proved by another train of reasoning. In connexion with the two former styles, we find many approaches to the *form*, but none to the *principle*, of the *arch*;‡ whereas a perfect and well

* Colonel Leake says a generation later; ii. 355.
† Encycl. Britan. Articles, Homer and Troy.
‡ See Drawing IV.
Hughes' Travels in Greece, i. 223. Note.

Roman Arch surmounting a polygonal Wall.
Ferentino

Polygonal Walls, Ferentino surmounted
by regular Masonry & the Opus incertum.

**V**



IV

1

Gate at
Norba Latium

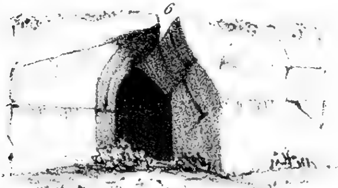
4

Cyclopian Gate at Tiryns. n. 5

2

Cyclopian Gate
at Tiryns.

6



Cyclopian Gate Signi

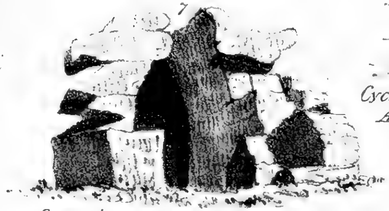
3

Gate at Signi

5

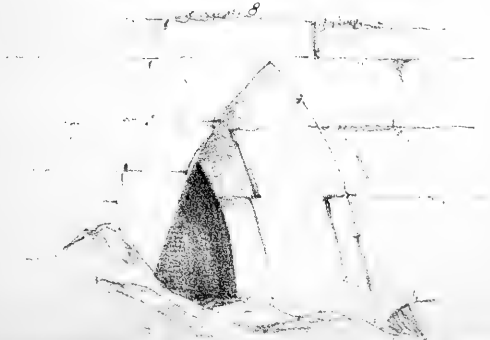
Cyclopian Archway
Arpino, Latium

7



Cyclopian Gateway, Terracina

8



finished arch is the common gateway of fortifications of the third style.*

I have, as yet, been able to discover no exception to this rule. In some cases as at *Ferentino*, in Latium,† the arch has been formed in walls of the polygonal order, but on a closer examination, it is always obvious that the arch was a subsequent addition, either of *Roman* or *Etruscan* architects. In the two earlier orders it is curious to trace the regular advance from the rudest gateway, constructed of two upright stones, and one horizontal, to the pyramidal form, and then gradually bending, till it approached more and more nearly to the semicircle.—Drawing IV. gives a series of these, from *Mycenæ*, *Thorikos*, *Arpino*, *Segni*, &c.—Excellent specimens of the perfect arch, as connected with *Etruscan* walls, may be seen in drawing V. which represents gateways at *Volterra* and *Fiesole*.

Some authors, however, and among them Col. Leake,‡ seem to consider the *Treasury of Atreus*, (a dome-shaped building, which I described in a

* See Drawing V.

† See Drawing VI.

‡ Travels in the Morea. II. 380.

former paper,*) as indicating an acquaintance with the principle of the arch. But (setting aside the consideration already alluded to, as to the later date of this splendid building,) this idea appears to me a mistaken one. In the Treasury, as may be seen in the accompanying section,† given by *Col. Leake* himself, there is no keystone, properly so called; the dome is terminated by a large stone, laid flat over the top of it, and the whole is kept in shape only by the weight of the superincumbent earth.

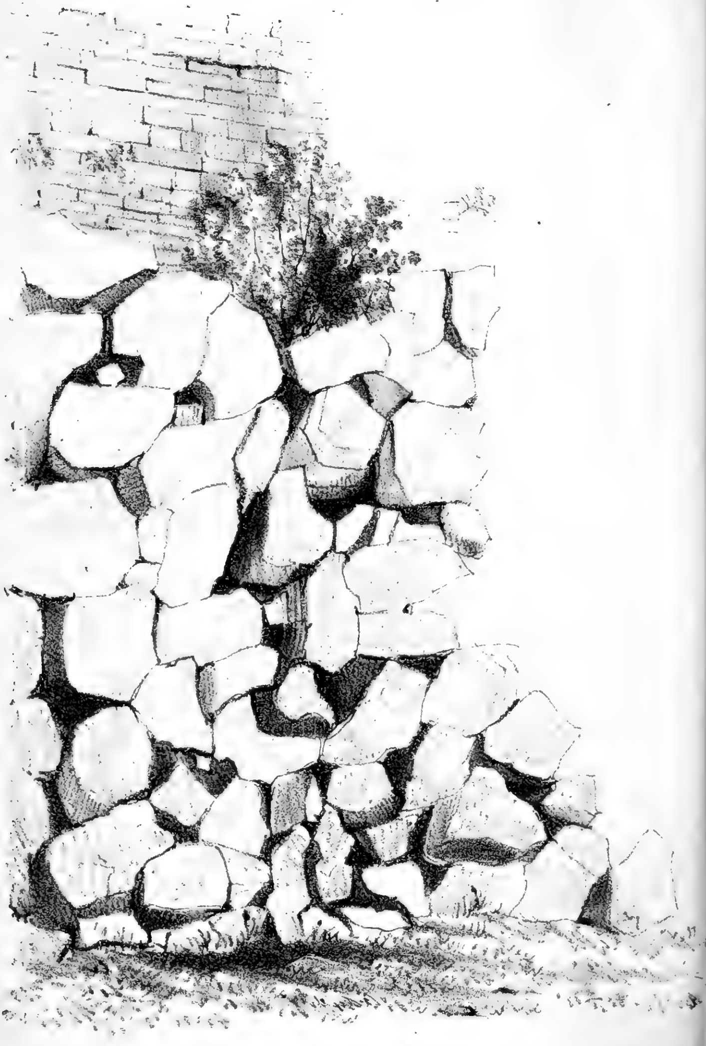
We may, therefore, I think, conclude, with as much confidence as can ever attend any conclusion respecting events so distant and obscure, *that the Mural Architecture*, which dates before the historical era, is referrible to three distinct styles, if not to distinct ages, and distinct people.

II.—Let us now proceed to consider the second question, viz.: "To whom these various fortifications are to be attributed, and why they have received their present names?"

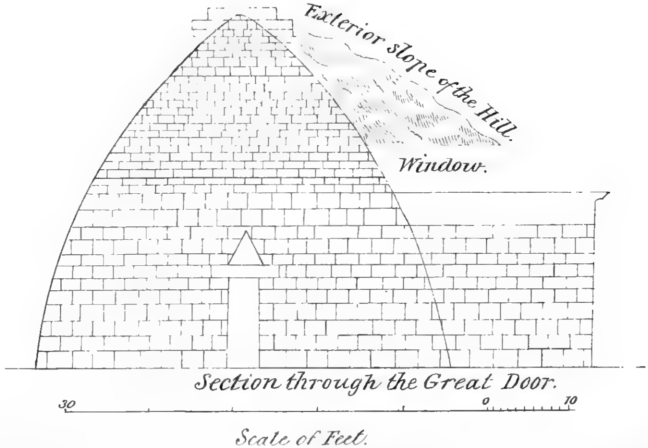
I. With regard to the amorphous style, of

* Drawing VII.

† Drawing VIII. from Leake's Morea.



*Fragments of the Walls of Cora*




Treasury of Atreus.

which the only three certain specimens extant are at *Lycosura*, *Tyrins*, and portions of the walls at *Mycenæ*,—I say, "the only three *certain* specimens," because some imagine that they have found samples of the shapeless, unhewn style, at *Cora* and *Volterra*, the one a *Pelasgic*, the other an *Etruscan* city.* A closer examination, however, renders it extremely probable, indeed I may say certain, that these portions originally resembled the rest of the walls to which they belong; but that the edges of the stones having been worn away to a considerable depth by the influence of wind and moisture, causes the appearance which the drawing represents. This is the more probable, as in both cases they stand at the foot of a steep descent, down which, in the rainy season, the water pours like a torrent; and both face the South East, and are consequently exposed to the Sirocco, the most corroding wind in the world. This view of the subject is confirmed by the *Signora Dionigi*, in her elaborate work on the Latian Cities, p. 47.

Of the ruins of *Lycosura*, we know very little. They are described by *Dodwell*, in his magnificent work on Cyclopian Structures,† as similar to

* Drawing IX.

† P. 1. fol.

those of *Tyrins*. Of its history we know too little to throw any light upon the present inquiry. *Pausanias** says it was "the eldest of cities, the first on which the sun ever shone, and the model to succeeding generations;" but he does not explain the style of its architecture, nor by whom it was built. *Apollodorus*† informs us that it was founded by *Lycaon*, son of *Pelasgus*. I can find no mention of it in *Strabo*; probably he overlooked its ruins, as he had done those of *Mycenæ*‡.

Respecting *Tyrins* our information is more satisfactory. *Pausanias*, who visited it in the second century after the Christian era, and describes its remains with great accuracy, says, "it took its name from *Tyrinthus*, son of the Argian Jove, and was the work of the Cyclopes."§ *Strabo*‖ says it was used as a citadel by Prœtus, for whom it was built by seven *Cyclopes*, whom he summoned out of *Lycia* for the purpose. *Homer*¶ speaks of Tyrins with an epithet (τειχιοεσσαν) which shows

* B. 8. c. 38. πολεων δε .............. Λυκυσουρα εστι πρεσβυτατη και ταυτην ειδεν ὁ ηλιος πρωτην. απο ταυτης δε οἱ λοιποι ποιεισθαι πολεις μεμαθηκασιν ανθρωποι.

† B. iii.

‡ He says (B. viii. 547.) αι μεν ουν Μυκηναι νυν ουκετι εισιν.

§ Book ii. c. 25.

‖ Book viii. p. 540.

¶ Iliad. ii. 559.

that in his time its walls were considered wonderful and characteristic.

*Pausanias** tells us that it was believed by the Greeks, (or rather *known*, for he says ισασιν Ελληνες:) that *Mycenæ* was founded by *Perseus*, and that the Gate of Lions was the work of *Cyclopes*, who fortified *Tyrins* for *Prætus*.† *Strabo*, who confirms the statement of its foundation by *Perseus*, declares that in his time (A. D. 20.) no vestiges of it were extant‡. *Euripides* mentions it in seven or eight passages in his plays,§ and always as the work of the *Cyclopes*, and once as the city of *Perseus*.

This is (I believe) the sum of the information we possess, regarding ancient fortifications of the amorphous style. It seems, then, perfectly clear, that the ancients universally attributed them to a people called the *Cyclopes*. "Who, then, and

* B. ii. c. 15.
† B. ii. c. 16.
‡ B. viii. 547.
§ Orestes, v. 963.
Iphigenia in Aulide, v. 152, 265, 534, 1500.
Iphigen. in Tauride, v. 844.
Troades, v. 1088.
Hercules furens, v. 944, 998.
Electra, v. 1158.

what were these *Cyclopes?* Were they a race wholly fabulous, and was the term Cyclopian, merely an epithet of grandeur, and not the statement of a fact; or were they a people of great mechanical skill, to whom the magnitude of their achievements, and the remoteness of their age, procured the reputation of gigantic stature, and superhuman strength?"

The latter supposition seems to me the most probable. The poets and historians of Greece, finding these stupendous fortifications, which far surpassed the skill and strength of their own times, and learning that tradition assigned them to a foreign race, called the *Cyclopes*, set their imaginations at work to conceive the attributes which ought to belong to the authors of such massive constructions, and invented the monstrous fables respecting them, which have descended to our days. Certain it is, that almost all the statements which exist concerning the *Cyclopes*, bear marks of pure fiction. To say nothing of the extraordinary description in the ninth book of the *Odyssey*, *Homer* speaks of them in more than one place as Giants.* *Pausanias* has a precisely similar expression.† *Euripides* describes them

* Ωσπερ Κυκλωπες τε και αγρια φυλα Γιγαντων.

† Ωσπερ Κυκλωπας και το γιγαντων εθνος.

as "sons of Neptune, one-eyed, homicides, and Cannibals;* and all the other notices we have of them, are equally wild and unsatisfactory, with two exceptions. *Strabo*† calls them γαστεροχειρας, or professional artificers—men who lived by the labour of their hands;—but that he also considered them to be giants, may, I think, be concluded from his statement, that only seven were employed in the fortification of *Tyrins*. *Pliny* speaks of them as the inventors of iron.‡

On the whole, we may, I think, venture to conclude that these fortifications are the work of a people who flourished before the historical era, probably thirty-two centuries ago; who had made great advances in the mechanical arts, and who were, in consequence, employed in constructing fortresses for the Greek chieftains, before the siege of Troy; and that subsequently, (as the annotator upon *Statius*§ observes,) whatever was distinguished by magnitude or grandeur, was attributed to them, and that out of these simple

* Cyclopes, v. 20. v. 93.

† B. viii. 540.

‡ Fabricam ferream invenere Cyclopes. Nat. Hist. vii. c.56. We learn from Pausanias, that a temple was erected to them on the isthmus of Corinth. ii. c. 2.

§ Lib. i. "Quidquid magnitudine sua nobile est, Cyclopum manu fabricatum dicitur."

materials tne Poets worked up their frightful fictions.

II.—Of the *Polygonal* style, few specimens are found in *Greece;* I believe part of the walls of *Mycenæ*, a fragment at *Argos*, and *Gortys*,* and another in *Epirus*,† are all that can fairly be referred to this order. *Hughes* says it is very common in *Magna Grecia* and *Tuscany*, whereas I believe no specimen exists in either country, except a few fragments at *Cossa*, in the ancient *Etruria*. With the above exceptions, we find the polygonal style in Latium, and in *Latium* only.‡ There it is to be met with in great abundance. *Norba*, *Cora*, *Alatri*, *Arpino*, *Ferentino*, and *Segni* present excellent examples, and fragments are found near *Tivoli*, at *Palestrina*, *Atina*, *Terracina*, and in many other situations.

These have in general been confounded with walls of the first order, no distinction whatever being made between them. *Dodwell*, *Hughes*, and others, class them together, and call them *Cyclopian; Peter Radel*, and after him *Middleton*,§

* Dodwell, fol. p. 12. Plate, XVIII.

† Hughes, i. 214.

‡ See Maps.

§ Grecian Remains in Italy, fol. p. 6.

and *La Signora Dionigi*, class them together, and call them *Pelasgic*, asserting that they are found only where the *Pelasgi* are known to have dwelt. Who, then, were the *Pelasgi*, and where did they dwell?

I confess myself unable to give any satisfactory answer to either of these questions. I have read what *Niebuhr*,* *Thirlwall*,† *Middleton*,‡ and *Micali*§ have been able to collect respecting them, and I have referred to several of the ancient authors from whom they quote,‖ but every additional investigation seems to cover the subject with additional obscurity, a fact which cannot be better expressed than in the hopeless summing up of *Niebuhr*, in his first edition.¶ "We must rest satisfied with the impossibility of determining with certainty what nation were the *Pelasgi*, how distinguished from the *Greeks*, and whether those who are mentioned as in different places, belonged to the same stock. Every notice of this people,

* History of Rome, third edition, I.

† Hist of Greece, I.

‡ Grecian Remains, fol. c. 3.

§ Italia avanti i Romani, I, c. 7.

‖ Herod. i. c. 57. ii. c. 136.
Homer, Iliad, ii. 840. Odyss. xix. l. 177.
Strabo, b. v. and xiii.

¶ Hist. of Rome, I. p. 36.

in the brightest, as well as in the darkest pages of their history, remains to us an enigma, the satisfactory solution of which will be most absolutely despaired of by him, who has most studiously laboured at its investigation." In his third edition, *Niebuhr* added much new matter, but no new light.

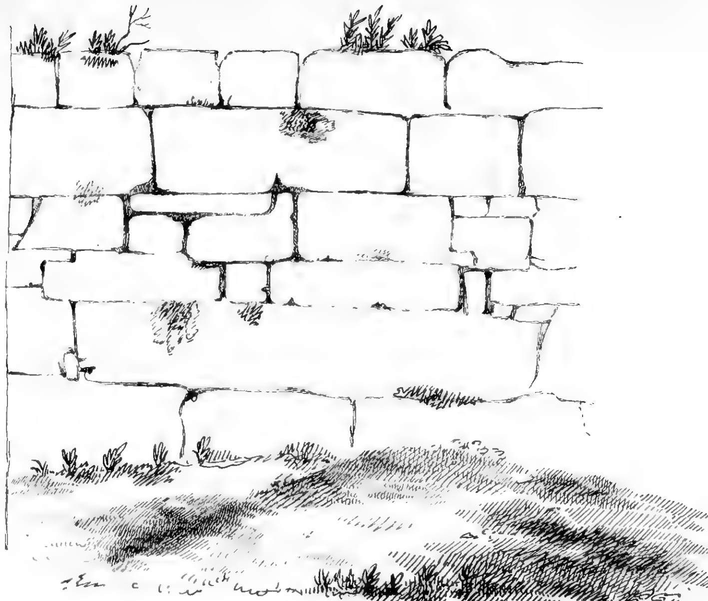
According to *Strabo*,* the *Pelasgi* inhabited *Thessaly* and *Epirus*, and from thence emigrated into *Italy*, where they built the city of *Cære*, in *Etruria*. Other writers speak of them in different parts of the *Peloponnesus*. Perhaps the sum of our actual information regarding them, may be comprised in the following meagre facts: That they were not one nation, but a number of tribes;† that they were wanderers;‡ that they existed long before the historical era; and that they either inhabited or over-ran, at different times, the greater part of Greece and Italy.

My chief difficulty in admitting the Polygonal walls to be the work of the Pelasgi is this—*Niebuhr* positively asserts their existence, both in

* B. v. p. 312. B. vii. 475.

† Homer speaks of the φυλα Πελασγων, Iliad, ii. 840.

‡ Strabo, b. xiii.



*Walls at Fiesole, an Etruscan City.*

Etruria and Magna Grecia. If, therefore, the Polygonal style is to be attributed to them, how is it that we find it in Latium alone? This, however, is a subject on which it is far easier to overthrow hypotheses, than to construct them; and I have no conjecture to substitute for the one which I am indisposed to admit.

III.—The third style of ancient Mural Architecture, which is distinguished by the vast uncemented masses of which it is composed, being arranged in horizontal courses, there is no reason to doubt, was the work of the Etruscans, whose name it bears;* a people who come almost within the range of history, and of whose early proficiency, both in the useful and the fine arts, we have ample proof in the remains which have come down to us. The best, and, I believe, the only specimens of this order now extant, are to be found within the limits of Etruria, and may be examined to advantage at *Volterra*, *Fiesole*, *Cortona*, *Populonia* and *Roselle*.† There is another style, which is often called *Etruscan*, but which is evidently of more modern date, and is distinguished from the *isodomon*, or regular masonry

* Micali, I. c. 10. II. c. 25.

† Drawing X.

of the Greeks, only by the joints being sloping, instead of vertical, as may be seen in Drawing XI.* Some specimens of this are certainly found in *Etruria*, and also at *Pompeii*, but abound still more in the ruins of ancient Greek walls, as at *Messalogion*, *Galaxidi*, *Delphi*, *Platea*, and *Pharsalia*.†

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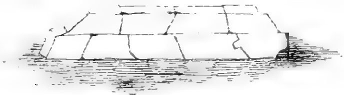
In the examination of these stupendous fortresses, especially those of the Amorphous and Polygonal orders, two questions force themselves upon our minds :—

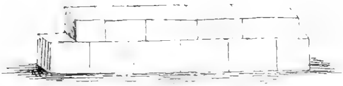
I.—What could have been the inducement of the architects to adopt the Polygonal style, which would seem to require more skill and labour than the regular cubes which the *Etruscans* employed, and which have since been universal?

II.—What means could they have possessed, in so rude and remote an age, for cutting, raising, and transporting such enormous blocks as these, which composed their walls?

* Drawing XI.
† Dodwell, fol.



Masonry at Pompeii.



Isodomon.

Walls at Galaxidi.

1. Their object in choosing so peculiar a style as the Polygonal, and fitting their blocks together with such minute accuracy, must either have been economy of labour, economy of material, or increase of strength and stability. The first of these could scarcely have been their aim, since the well-fitted Polygons must certainly demand greater care and toil than the regular masonry of the Greeks. It is difficult to see why they should have been anxious to economise materials, when their quarries were, in almost every instance, close at hand. I am, therefore, disposed to think that they were guided to this peculiarity of construction, by an opinion of its superior capability of resisting earthquakes, and other violence, in which idea they have certainly not been disappointed; for though these walls are chiefly found in a country which has been frequently the scene of subterranean convulsions, yet I could not discover a single instance in which they appear to have suffered from such agency.* This view of the subject is confirmed, by finding that precisely the same principle, (the employment of large Polygonal masses,) was adopted by the *Romans*

* Middleton, fol. p. 7.

in the construction of their roads, as we see in the *via Appia*, and the streets of *Pompeii*.* The same system is now in use throughout the chief cities of *Tuscany*,† and pavements so constructed are found to outlast any others, and to be much less frequently displaced by the heavy loads which pass over them. It is worthy of admiration, that the most ancient structures should thus be the most durable also. Many of these walls are as perfect now as they were 2000 years ago, and may rival the *Pyramids* in their boast of an earthly eternity.

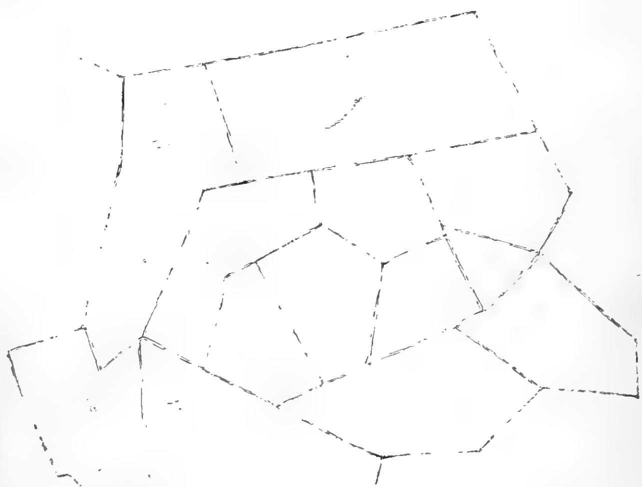
2. Such powerful instruments—such combined exertion—such command over the mechanical powers as are indicated by the ancient fortifications we are considering, may well astonish us in a people, who lived long before the age when authentic history commences, and in times which we are accustomed to consider barbarous, and who have left no record of their existence, except in those stupendous structures, which were regarded by subsequent generations as surpassing human power. With regard to the means which these

* Drawing xii.

† Drawing xiii.

*Pavement of the Via Appia.*

XI



*Pavement in Florence.*

architects employed, we are left wholly to conjecture. That their fortifications were the result of the combined labour of multitudes, there can be little doubt. *Niebuhr** conceives them to have been executed by an enslaved people, acting under the direction of a severe and scientific priesthood. *Herodotus*† expressly states that this was the case with regard to the *Pyramids*, in which he is confirmed by *Goguet*,‡ *Voltaire*, and *Larcher*.§ There is, I believe, only one passage in any ancient author, which pretends to throw any light upon the instruments employed in the construction of the early fortresses. *Euripides*‖ tells us that the walls of *Mycenæ* were "built with Phenician rules, and stone-cutters' chisels." Of the employment of such instruments there is little doubt; but they are not sufficient for the effect produced, as will be obvious when we consider the weight of many of the stones, which enter into

* Hist. of Rome. i. p. 87 and 119. First (English.)

† B. ii. 124.

‡ Origine des Lois, &c. iii. p. 57.

§ Note to Herod, as above.

‖ Hercules Furens. 946.

Φοινικι κανονι και τυκοις.

See also Müller—Archæologie der Kunst, p. 28.

the construction of these walls and the height to which they were raised*.

*Goguet*, in his account of the state of the arts among the *Egyptians*, conceives the stones of the *Pyramids*, (which he dated B. C. 900,) to have been raised by the use of *levers* alone ;† and he gives a drawing of the manner in which he considers it to have been executed‡. His views, are, however, liable to two objections. *Herodotus*§ expressly states the instruments employed to have been composed of "short pieces of wood," whereas the levers represented by *Goguet* are at least 50 feet long, and must have been so, in order to gain a sufficient purchase. Further, it is difficult to conceive how any wooden levers could have been of sufficient strength to raise stones of such a weight, (27 tons), without being so enormous and unwieldy as to surpass the skill of any number of men to manage them ; and if they were of iron,

| | ft. | | ft. | | ft. | | Tons. |
|---|---|---|---|---|---|---|---|
| * Thus we find stones at Tyrins ... | $10\frac{1}{2}$ | × | 4 | × | $3\frac{1}{2}$ | = | 10 |
| Mycenæ . | 15 | × | 4 | × | $6\frac{1}{2}$ | = | 27 |
| Alatri ... | 12 | × | 5 | × | $6\frac{1}{2}$ | = | 16 |
| Norba ... | 10 | × | $4\frac{1}{2}$ | × | 3 | = | 9 |
| Pyramia . | 30 | × | 4 | × | 3 | = | 25 |

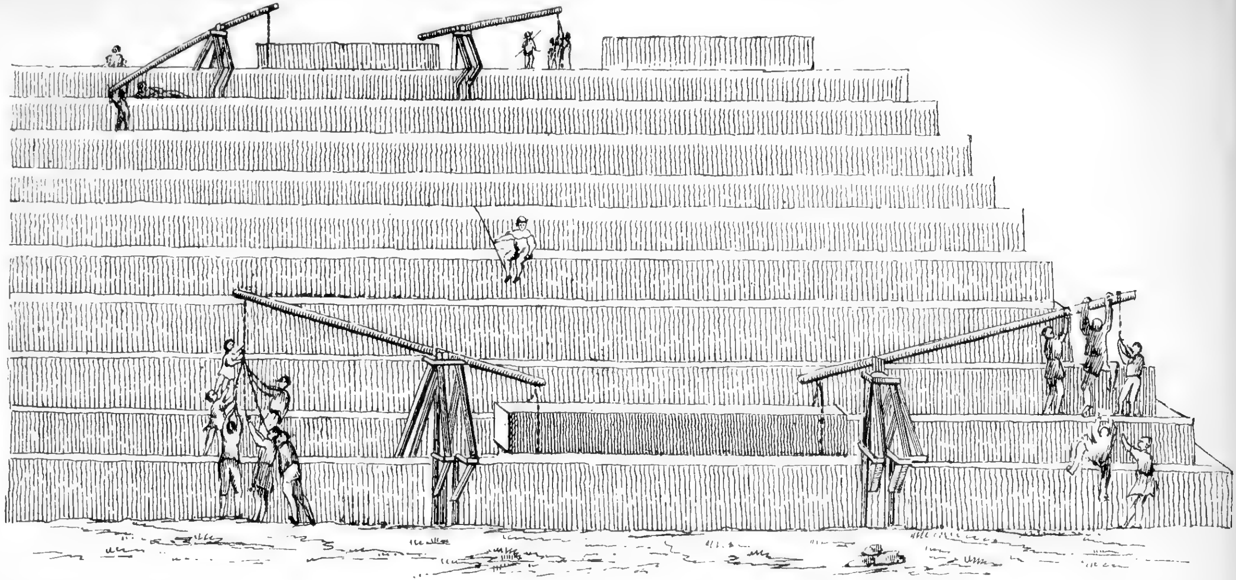
N. B.—The Architrave of the Propylæum at Athens is 22 feet long.

† iii. p. 58.

‡ Drawing xiv.

§ ii. 125.

XIV



MODE OF BUILDING THE PYRAMIDS

*from Goguet*

(which *Herodotus* says they were not,) it may well be doubted whether they could be made of adequate strength, without being nearly as heavy as the block they had to lift. *Diodorus** speaks of the inclined plane having been used in their construction, and one commentator conceives the machines mentioned by *Herodotus* to have been pulleys. The mass of combined labour which a system of slavery places at the command of the master, with two such powers as the pulley and the inclined plane, would certainly be equal to the construction of all the buildings in question, and I conceive scarcely any other means would; and if these powers were known and used in so remote an age, what an impression does this give us of the advanced civilization of a people who had invented and employed them a thousand years before our era!

On the whole then, the conclusions we may draw, respecting the stupendous fortifications we have been considering, are reduced to this limited amount:

That they all took their origin before the birth of authentic history, and that some of them have

* B. iv. p. 73.

already defied the hand of time for upwards of thirty centuries.

That they were the productions of different times, if not of different people.

That they were erected by a people possessed of a high degree of mechanical skill, and considerable command of machinery, and sufficiently civilized to build for succeeding generations, who existed at a period when we are accustomed to consider the whole of Europe as plunged in the darkest barbarism.

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## APPENDIX.

Description of the Palace of the Incas, at Latacunga, in the Province of Quito. From the Travels of Don Antonio de Ulloa. Madrid, 1748.

"The materials of this building are stone, as hard as flint, and of a black colour. The separate stones are so well worked and fitted together, that it is not possible to introduce between them the

edge of a knife, the joints being finer than the thinnest paper, just sufficient to make the observer aware that the entire wall is not composed of one single stone.

"No cement has been made use of, and on the outside all the stones have been worked to a convex surface. What renders this work more extraordinary, is, that a large and imperfectly squared stone succeeds to a small one, and the one above them accommodates itself to the inequalities of both, no less than to the convexities and irregularities of the surfaces of each, and all this with such perfection, that, on whatsoever side it is examined, the same exactness may be observed.

"The walls are about $2\frac{1}{2}$ toises (15 to 16 feet) high, and from three to four feet thick."—*Ulloa*, book vi. chap 11.

The round tower of Kilmacdaugh, in Ireland, built probably about the 9th century, 110 feet high, is built of stones of all sizes, some extremely large, fitted together precisely like those of the Cyclopian fortresses of Greece.

# ON THE RELATIVE ATTRACTIONS OF SULPHURIC ACID FOR WATER,

## Under particular circumstances:

### WITH SUGGESTION OF MEANS OF IMPROVING THE ORDINARY PROCESS OF MANUFACTURING SULPHURIC ACID.

BY HENRY HOUGH WATSON,
CORRESPONDING MEMBER OF THE SOCIETY.

(Read 16th of April, 1839.)

THOUGH it has been long known that concentrated sulphuric acid, in consequence of its great attraction for water, robs the atmosphere of its vapour, and becomes thereby itself diluted; and though its drying agency is frequently adverted to in our laboratories in cases of research, where drying by the application of heat would be objectionable; I do not know that any person has hitherto attempted to trace out by experiment the limits within which the acid in question is a drier of the atmosphere. Works on chemistry

give us no information on the subject; but, from some of them, we learn that experiments have been made on the extent to which the acid becomes diluted by exposure to the atmosphere; these experiments, however, being so limited in their nature as to fall far short of eliciting that information which it has seemed to me desirable for us to possess. In Dr. Ure's Dictionary we are told that, if suffered to remain in an open vessel, it imbibes one-third of its weight in 24 hours, and more than six times its weight in a twelve month. And in Dr. Thomson's System of Chemistry we are told that Newman found, that, when exposed to the atmosphere, it attracted 6.25 times its own weight; and that Mr. Gould found that 180 grains of it, when exposed to the atmosphere, attracted 68 grains of water the first day, 58 the second, 39 the third, 23 the fourth, 18 the fifth, and at last only 5, 4, 3, &c.; the 28th day the augmentation was only half a grain. We are not informed in what state of dryness the atmosphere was during these exposures, nor have we anything beyond evidence that sulphuric acid has a strong attraction for water.

In the course of some experiments which I was some time ago conducting to ascertain the

per centages of water in the crystals of some soda salts, by submitting them to the drying agency of a vacuum accompanied by a vessel of sulphuric acid, the results of which were communicated to this Society, I frequently felt at a loss to know whether the acid I had under the receiver was sufficiently strong to render the space perfectly anhydrous; or, indeed, to render it sufficiently dry to deprive the salts under operation of as much water as anhydrous space could do; and, consequently, I much more frequently renewed the acid than was really requisite. The annoyance of doubt, thus frequently felt in impairing that spirit of confidence which always ought to accompany philosophical investigation, proved itself a stimulus to subsequent experimental inquiry, the result whereof furnishes us with facts on which we may, I hope, rely in after research; and adds, though little, in assisting to fill up the vast hiatus remaining to be filled up before our knowledge of Nature's laws can be said to be complete.

The object of my inquiry was, to determine at what degree of concentration the affinity of sulphuric acid for aqueous vapour is equal to that of anhydrous space for the same vapour at particu-

lar temperatures. To effect this object, the experiments which I now commence relating were undertaken.

EXPERIMENT I.

I put into a glass evaporating dish of known weight 200 grains of sulphuric acid, sp. gr. about 1.8428; and then intimately mixed therewith a little water, by which considerable heat was produced.* After the dish and contents had been cooled by immersion for a short time in cold water, it was found, by weighing, that the quantity of water which I had added was 15 grains. Into another similar dish I put 200 grains of the acid, but did not add thereto any water. Both dishes were then immediately placed under an exhausted air-pump receiver. On the following day I re-weighed them, and found that the one into which the 15 grains of water had been put had gained 0.6 of a grain, and the other 1.2

* It may be proper to observe, that the acid I used throughout my experiments was some which a friend of mine, Mr. H. Blair, an extensive manufacturer of the article, prepared for me with more than ordinary care. I found, by evaporation, that its total impurity amounted only to the 1-20th of one per cent. And 100 grains gave with nitrate of barytes 233 grains of sulphate, = 79 real, or anhydrous sulphuric acid.

grain. This additional water must have been acquired from the atmosphere while the dishes were in being transferred to and from the receiver.

It being evident that the undiluted acid had not taken from the diluted acid any of its water, I now added to the diluted acid 9.3 grains more water; and, with the same precautions as to cooling as before, placed both dishes again under the exhausted receiver. In a few days they were re-weighed, when the diluted acid was found to have lost 1.1 grain, and the undiluted to have gained it. Both were again put under the receiver, and by several times weighing and replacing them there, the diluted acid was found to lose weight, until the total loss was 1.9 grain. Had the experiment been continued, a little further loss would have been sustained; but being able to guess, as I imagined, from what had already taken place, to about the extent to which concentrated acid would bear diluting, without having its affinity for water so much diminished as to be compelled to yield to the attractive agency of anhydrous space, I resolved upon recommencing the experiment; and, consequently, on the 22d September, 1837, I put into one dish

200 grains of the acid, sp. gr. 1.8428, diluted in the manner described before, with 23.3 grains of water (23 grains being the quantity with which the 200 grains of acid were in a state of dilution at the conclusion of the experiment in the other instance,) and into another dish 200 grains of the acid without being diluted. Both dishes were kept under the exhausted receiver as before. On the 29th September the diluted acid was found to have lost 1.3 grain; on the 6th October, 1.7 grain; and on the 13th, 2.4 grains: on the 20th and 27th, the weight was exactly the same as on the 13th; the concentration being evidently carried to as high a degree as the evaporating agency of anhydrous space, under the circumstances of the case, would admit of.

Now, by deducting 2.4 from 23.3, we find that the quantity of water which the 200 grains of concentrated acid retained is 20.9 grains, or that 100 grains of the acid retained 10.45 grains of the water added. Admitting that the concentrated acid contained 79 per cent. real, it must also have contained 21 per cent. of water:—we then have $21+10.45=31.45$ the total quantity of water diluting 79 real acid at the conclusion of the experiment; and $79 + 31.45 = 110.45$ the

total quantity of diluted acid remaining in the dish; the per centage of real acid in which being 71.53 nearly; acid of this strength is of about the sp. gr. 1.814.

The temperature of that particular part of the room in which this air pump experiment was made, was regularly registered three times a day, whereby it was perceived that from the 22nd September to the 6th October, the temperature never ran higher than 65°, and from the 6th October to the 13th, not higher than 57°; from the 13th to the 27th, it was also frequently as high as 57°; hence it follows, that an evaporating force of 0.61 of an inch of mercury, has, in the instance of this experiment, been sufficient to concentrate the acid down to the sp. gr. 1.814; and, consequently, that acid of such strength is capable of drying a vacuum when the temperature does not exceed 57°.

### EXPERIMENT II.

On the morning of the 3rd October, 1837, I put into two light evaporating dishes, of $2\frac{1}{4}$ inches in diameter, 10 grains by weight of diluted sulphuric acid, sp. gr. 1.135; and the dishes, after being moved about until the acid had spread itself

over the whole surface of the bottoms, were left exposed to the atmosphere in a room without fire. They were re-weighed every morning during the continuance of the experiment, and several times moved about every day to agitate the contents. The temperature and vapour point of the room were accurately ascertained, and registered three times a day.* On the 4th October, each dish was found to have lost 3.2 grains, and on the 5th 4.3 grains; on the 6th each was found to have regained 0.2 of a grain, and on the 7th their weights were exactly the same as on the 6th. In each case, therefore, the weight of the diluted acid on the 6th and 7th, was 4.1 grains less than when put into the dish. The loss of water was 41 per cent; the liquid remaining in each dish being 5.9 grains. If we suppose 100 grains of the diluted acid to have been used in this experiment instead of 10, they would have been reduced to 59 grains, those 59 grains containing all the anhydrous sulphuric acid which was in the 100 grains of the diluted acid experimented upon, viz. 15.8 grains;† the per centage, therefore, of

* The vapour point was ascertained by Dr. Dalton's method.

† By treating 100 grains of this diluted acid with nitrate of barytes, I obtained 46.7 grains of sulphate, = 15.8 anhydrous sulphuric acid.

anhydrous acid in the 59 grains remaining in the dish, being nearly 26.78.

In order to understand the state of the atmosphere during the experiment, it is necessary to appeal to the register of the temperature, and vapour point, of which the following is a copy.

| 1837. | TEMPERATURE. | | | VAPOUR POINT. | | |
|---|---|---|---|---|---|---|
| Oct. | Morn. | Noon. | Night. | Morn. | Noon. | Night. |
| 3 | 61° | 63° | 64° | 53° | 55° | 56° |
| 4 | 64 | 65 | 63 | 56 | 56 | 53 |
| 5 | 59 | 63 | 62 | 50 | 54 | 53 |
| 6 | 63 | 63 | 62 | 54 | 54 | 53 |
| 7 | 60 | 62 | 62 | 51 | 53 | 53 |
| 8 | 62 | 62 | 61 | 53 | 54 | 52 |

The annexed table shows the evaporating force of the atmosphere, or the affinity of space for vapour, as ascertained by deducting the force of vapour at the temperature of the vapour point from its force at the temperature of the atmosphere; the forces of vapour at the respective temperatures being taken from the table in the second volume of Dr. Dalton's New System of Chemistry; and which, as I have frequently to refer to it, I have copied into a subsequent part of this paper.

| 1837. | EVAPORATING FORCE. | | |
|---|---|---|---|
| Oct. | Morn. | Noon. | Night. |
| | Inch of Mer. | Inch of Mer. | Inch of Mer. |
| 3 | 0.13 | 0.13 | 0.14 |
| 4 | 0.14 | 0.16 | 0.17 |
| 5 | 0.15 | 0.15 | 0.15 |
| 6 | 0.15 | 0.15 | 0.15 |
| 7 | 0.15 | 0.15 | 0.15 |
| 8 | 0.15 | 0.13 | 0.15 |

On comparing the results of the several weighings with this register of evaporating force, we observe that weight was found to be lost till and on the morning of the 5th, and that from the commencement of the experiment to that time the evaporating force had ranged from 0.13 of an inch of mercury to 0.17 of an inch. We also observe that on the morning of the 6th a slight regain of weight was found; and that from the morning of the 5th to that of the 6th the evaporating force had all the time been stationary at 0.15 of an inch of mercury. Up to the night of the 4th the acid had become concentrated to such a degree as that it was capable of resisting an evaporating force of 0.16 or 0.17 of an inch of mercury; and when the evaporating force happened to be reduced on the 5th to 0.15 of an inch, the acid was so far capable of overcoming that force as to regain 0.2 of a grain, and to retain that on the 6th, and as long as the evaporating force remained as then.

I have stated, that on the 6th and 7th the concentration of the acid had extended so far as to cause the per centage of real, or anhydrous, acid in the residue in the dish to be about 26.78 ; acid of such strength is of about the sp. gr. 1.249. Hence, it follows that when the affinity of space for vapour, or the evaporating force, is equal to 0.15 of an inch of mercury, it is just able to balance the affinity of sulphuric acid sp. gr. 1.249 (or such at least as contains 26.78 per cent. of real) for water.

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It is well known that ordinary evaporation from water goes on at a greater *rate* in vacuo than in air under atmospheric pressure ; and it might obviously be expected that the rate at which water would evaporate from diluted sulphuric acid would be greater in vacuo than in air; but, at the conclusion of the experiments I have related, it seemed to be matter worth investigation to ascertain whether the evaporation of water from diluted sulphuric acid was capable of being carried on to the same *extent* in air as in vacuo ; or, in other words, whether the same strength of acid was required to render air at its usual pres-

sure anhydrous, as was required to render a vacuum of the same temperature anhydrous. And, accordingly, on the 1st of November, 1837, I commenced two comparative experiments, with the view of acquiring this desirable information.

### EXPERIMENTS III. AND IV.

Into one light evaporating dish of $2\frac{3}{4}$ inches in diameter I put 200 grains of the sulphuric acid, sp. gr. 1.8428, and diluted it with 24 grains of water, (attending to the precautions mentioned in the instances of the former experiments). The dish, with its contents, was then placed upon an air-pump plate, along with another glass vessel of an equal diameter, containing several hundred grains of the concentrated acid, and covered with a receiver, which was immediately exhausted as much as the capability of the pump would allow.

Into another light dish of the same diameter I also put 200 grains of the acid, sp. gr. 1.8428, which I diluted with 24.2 grains of water. This dish, with its contents, was placed upon a ground brass plate, similar to that of the air-pump, along with another glass vessel of an equal diameter, containing several hundred grains of the concentrated acid, and covered with an air-pump receiver,

tallowed to prevent the passage of air, *but not exhausted.* This brass plate supporting the unexhausted receiver, was placed in the immediate neighbourhood of the air pump, so as to ensure the exposure of the two experiments to the very same temperatures.

In these states, the dishes, the objects of experiment, were kept till the 8th November, when that under the exhausted receiver, was found, by weighing, neither to have gained nor lost the slightest weight; but that under the unexhausted receiver, was found to be 0.7 grain heavier than at the commencement of the experiment. It being evident that the acid, in neither case, was sufficiently diluted to allow either a vacuum or dry air to rob it of any water at the temperatures it had been subjected to, the dilution was carried further. The acid in the dish under the exhausted receiver, had water added to it until the total quantity of water diluting the 200 grains of concentrated acid was 76.1 grains; and that in the dish under the unexhausted receiver, had water added till the total quantity diluting the 200 grains of concentrated acid was 75.5 grains: both dishes being placed under their respective receivers, were kept there, as before, till the 15th

November, when the one under the exhausted receiver was found to have lost 30.6 grains, while that under the unexhausted receiver had only lost 4 grains. Both experiments were continued, and the losses of weight afterwards found to be as follows :—

| 1837. | Total loss from the dish under the exhausted receiver. | Total loss from the dish under the unexhausted receiver. | Range of temperature to which the dishes, the objects of experiment, were exposed between the present and next previous weighing. |
|---|---|---|---|
| | Grains. | Grains. | |
| Nov. 22 | 37.9 | 6.9 | From 44° to 48° |
| " 29 | 42.4 | 9.9 | 45 to 53 |
| Dec. 6 | 44.9 | 11.9 | 43 to 48 |
| " 13 | 46.0 | 13.3 | 43 to 45 |
| " 20 | 46.9 | 14.8 | 44 to 53 |
| " 27 | 48.1 | 16.4 | 49 to 54 |
| 1838. | | | |
| Jan. 3 | 49.2 | 17.4 | 49 to 53 |
| " 10 | 50.0 | 18.4 | 39 to 49 |
| " 17 | 50.2 | 19.1 | 34 to 39 |
| " 24 | 50.2 | 19.2 | 34 to 39 |
| " 31 | 50.5 | 20.1 | 42 to 47 |
| Feb. 7 | 50.6 | 20.8 | 42 to 44 |
| " 14 | 50.8 | 21.4 | 42 to 44 |
| " 23 | 51.5 | 22.4 | 40 to 46 |
| March 2 | 51.6 | 22.7 | 42 to 46 |
| " 9 | 51.9 | 22.9 | 46 to 49 |
| " 16 | 52.3 | 23.3 | 48 to 53 |
| " 23 | 52.6 | 23.8 | 46 to 48 |
| " 30 | 52.6 | 23.8 | 45 to 48 |

As I could not, on the 30th March, detect any loss of weight to have taken place in either experiment, between then and the 23d, and as the

temperature had during the greater part of that interval been 48° (the maximum temperature of the previous week's interval,) I conclude that the acid the subject of each experiment, had become concentrated to as high a degree as it was capable of being, under the circumstances, and by no higher a temperature than 48°.

Then, $76.1 - 52.6 = 23.5$ grains of water diluting the 200 grains of concentrated acid (sp. gr. 1.8428,) at the conclusion of the experiment under the exhausted receiver. And, $75.5 - 23.8 = 51.7$ grains of water diluting the 200 grains of concentrated acid, at the conclusion of the experiment under the unexhausted receiver.—The acid in the dish under the exhausted receiver, was, therefore, so far concentrated as to contain 70.69 anhydrous acid per cent.; and that in the dish under the unexhausted receiver, 62.77 per cent.

It appears, from the results of these experiments, that weaker acid is required to render atmospheric air, at its usual pressure, anhydrous, than what is required to render a vacuum, of the same temperature, anhydrous; or, that the evaporating force of air, exerted upon diluted sulphuric acid, is less than that of a vacuum

of the same temperature. In opposition however, to this conclusion may perhaps be urged the apparent probability that the *air* was never, during the whole course of the experiment, rendered *really anhydrous*; that the concentrated acid might be incapable of depriving it of *all* its water, though it might be able to take some from it, and thereby give it a drying power great enough to cause it slowly to take water from the diluted acid, until the latter had acquired that degree of concentration which it was found to be of at the end of the experiment: but, bearing in mind that the maximum temperature to which the experiment was exposed, from the 23d to the 30th March, was such as would have been expected to give the space, if anhydrous, occupied by the air, a drying power equal to 0.46 of an inch of mercury, the experiments which I shall now mention will, I think, sufficiently show, that the concentrated acid was capable of depriving the air, or the space it occupied, of all its water, and of giving it the extreme evaporating force its temperature would admit of.

EXPERIMENT V.

I diluted 100 grains of the concentrated acid, sp. gr. 1.8428, in a dish of $2\frac{1}{4}$ inches in diameter,

with 15.2 grains of water, and left it, along with undiluted acid in another dish, under an unexhausted receiver (no larger than just requisite to cover the two dishes) standing in a plate of oil, from the 12th February, 1838, to the 22nd March, exposed to a temperature ranging each day as high as 65°, sometimes as high as 77°, and never lower than 50°; during this time, the diluted acid lost no weight. Now, the maximum evaporating force of the temperature to which the acid in this experiment was subjected, was equal to 1.06 inch of mercury; and yet the acid lost by its action no water, though in a more dilute state than acid concentrated to the utmost under an exhausted receiver at the temperature of 48°, or with an evaporating force of only 0.46 of an inch of mercury.

## EXPERIMENT VI.

I also diluted 100 grains of the concentrated acid, in a dish of the same size, with 14 grains of water, and left it, with concentrated acid, under a similar unexhausted receiver standing in mercury, for a period of 23 days, in a stove, the temperature of which (as found by observations made three times a day) ranged from 76° to 96°, but chiefly between 85° and 91°; and though, as

the maximum and minimum temperatures indicate, the evaporating force ranged from 1.03 to nearly 1.9 inch of mercury, the acid allowed to evaporate none of the 14 grains of water with which I had diluted it.

The experiments I have now related, offer conclusive evidence, to those to whom such has hitherto appeared to be wanting, that vapour exists in air as a fluid *sui generis;* or, that the evaporation of water is not owing to the existence of a chemical affinity between the vapour of that liquid and atmospheric air.

By those convinced that evaporation is not the consequence of a chemical affinity being exerted between vapour and air, two distinct notions have, in the case of evaporation from pure water, been entertained on the reason why evaporation does not go on so rapidly in air as in vacuo: one, that the retardation is owing to the *weight* of the atmosphere; and the other, that it is owing to the *vis inertiæ* of the particles of air; that vapour in ascending from the surface of water into the atmosphere, has to perform a circuitous route, similar to that which water has to take in descending through pebbles; this reason being consi-

dered to be supported by the circumstance of a vacuum, to which water is exposed, becoming instantaneously saturated with vapour, whilst dry air, on being exposed to water, is a comparatively long time over becoming saturated; together with the supposed fact, that space, whether full or void of air, is capable of retaining the same quantity of vapour, while the temperature remains the same. However tenable this reason may be as regards evaporation from water, something further seems to claim our adoption in regard to the evaporation of water from diluted sulphuric acid; for, if the *vis inertiæ* of the particles of air be the sole cause of the retardation, evaporation, though more slow in air than in vacuo, should go on until *as much water* has left the acid as would leave it in vacuo of the same dryness and at the same temperature,—which does not accord with experiment.

From the results of my experiments, it appears to me unavoidable that we should adopt the notion that the *weight* of the atmosphere is the true cause of the retardation:—it has, however, been asserted, that if the weight was the cause, it would effectually prevent *any* vapour from arising from water below the temperature of 212°; but,

as it is admitted, in support of the argument of the retardation being owing to the *vis inertiæ* of the particles of air, that the obstruction exerted by the atmosphere to vapour escaping from the surface of water is overcome in proportion to the force of the vapour, and as the force of vapour is increased by an increase of temperature, I see no reason why vapour should not arise from water under atmospheric pressure, at *low* temperatures, and in a degree proportionate to the force of vapour at those temperatures.

I am not aware that other incontrovertible facts have been adduced in support of the notion, that the weight of the atmosphere is the cause of evaporation going on more tardily in air than in vacuo. The fact of water and other liquids boiling, under diminished pressure, at temperatures very low in comparison with the temperatures at which they boil under the usual atmospheric pressure, may, by some, be considered sufficient foundation, whereon to ground such opinion ; but, this alone is not indubitable evidence ; indeed, it equally supports the opposite notion ; for, the characteristic appearance of ebullition being only owing to bubbles of vapour, formed at the bottom of the containing vessel, rushing through the liquid

and bursting forth at its surface,—an effect caused by an equilibrium of force being established in such instance between the tendency of the liquid to assume the elastic state, and the tendency of the atmosphere to resist that change, it certainly would be equally plausible to assert, that this equilibrium takes place at a low temperature, in a vessel exhausted of air, in consequence of the removal of innumerable small particles through which those of vapour must otherwise have filtered, and in order to facilitate this escape past such immovables at the ordinary pressure, the repulsive force of additional heat is indispensable; as it would be to assert, that ebullition takes place, in a vessel exhausted of air, with so little assistance from the repulsive agency of heat, in consequence of the removal of a weight which, in ordinary instances, presses upon the surface of the liquid whose tendency in a free state is to become aeriform.

I cannot but concur in the view held by Dr. Faraday, (Phil. Trans. 1826) that *a limit exists to the production of vapour from bodies;* nor does it appear needful to assign to any other agency than the attraction of cohesion the cause of such limit. And, so far as the experiments

under consideration are concerned, it seems that the weight of the atmosphere, by the slight compression which it exerts, gives some additional cohesion to the particles of liquid; or increases the affinity existing between the acid and the water with which it is diluted, to counterbalance which more of the repulsive agency of heat is required.

Having demonstrated that the evaporation of water from sulphuric acid is capable of being carried further in space void of air, than in space under ordinary atmospheric pressure, it becomes my duty to state the degree of rarefaction of the receivers I have spoken of as exhausted or regarded as *vacua*, and also to state under what degree of pressure the experiments were conducted, which I have described as conducted under unexhausted receivers. As I have for some years regularly registered the indications of the barometer, I am fortunately enabled to furnish with tolerable precision both these requisites. In every instance of an experiment under rarefied air, the exhaustion was such as that the mercury gauge indicated a pressure of only 0.9 of an inch; this being the utmost degree of rarefaction which the state of my pump, during the conducting of

the experiments, would admit of. I will, however, proceed to give the results of the remainder of my experiments, and defer the comparison of pressures to a subsequent part of the paper.

The foregoing experiments were conducted generally at temperatures considerably above the freezing point of water; but, the frost, at the beginning of the year 1838, gave me an opportunity of experimenting at temperatures ranging about that point.

### EXPERIMENTS VII. AND VIII.

On the 16th January, 1838, 100 grains of sulphuric acid, sp. gr. 1.135, containing 15.8 grains of anhydrous acid, were put into a light evaporating dish of $2\frac{3}{4}$ inches in diameter. The dish was gently heated upon a sand bath until $66\frac{1}{2}$ grains of water were expelled; the quantity of acid and water remaining in the dish being only $33\frac{1}{2}$ grains. The dish with its contents was then placed, along with a vessel containing concentrated acid, under an unexhausted receiver standing in a plate of oil, and left in a place of low temperature.

Into another evaporating dish of the same size,

was also put 100 grains of the acid, sp. gr. 1.135; this was gently heated upon a sand bath, until the 100 grains were reduced to 31.9 grains, by the evaporation of 68.1 grains of water. It was then placed, along with a vessel of concentrated acid, under an exhausted receiver, upon a brass transfer plate, and left in the immediate neighbourhood of the other dish.

The losses of weight from the two dishes were found to be as follows :—

| 1838. | Total loss from the dish under the unexhausted receiver. | Total loss from the dish under the exhausted receiver. | Range of Temperature to which the objects of experiment were exposed between the present and next previous weighing. |
|---|---|---|---|
| | Grains. | Grains. | |
| January 19 | 0.8 | 6.4 | From 28° to 32° |
| " 20 | 0.9 | 7.0 | " 27 to 30 |
| " 21 | 1.0 | 7.2 | " 27 to 27 |
| " 22 | 1.4 | 8.0 | " 43 to 44 |
| " 23 | 1.7 | 8.1 | " 34 to 37 |
| " 28 | 2.6 | 8.6 | " 30 to 32 |
| " 31 | 3.1 | 8.6 | " 32 to 34 |
| February 3 | 3.5 | 8.6 | " 33 to 34 |
| " 7 | 4.0 | | " 32 to 34 |
| " 10 | | 8.6 | " 32 to 38 |

On the 28th January, the acid under the exhausted receiver was in a perfectly crystallized state : after weighing, a little warmth was applied to the dish, by which the acid immediately became fluid, without undergoing any appreciable

change of weight: in this fluid state, it was again left as usual in the place of low temperature, and in a few hours it again became entirely crystallized. In this crystallized state it remained, when the experiment was discontinued, on the 10th of February. It, therefore, appears, that a temperature, ranging from 30° to 32°, or an evaporating force of from 0.24 to 0.26 of an inch of mercury, was sufficient to concentrate the acid so far as to give it a per centage of 67.8 real or anhydrous acid, and a sp. gr. about 1.7762; and that, while crystallized, it had no apparent further concentration given it by an evaporating force extending even to 0.32 of an inch of mercury.

The acid under the unexhausted receiver continued to lose weight till the 2nd of March; at which time the loss was found to be 6.3 grains: the residue in the dish contained 58.1 per cent. of anhydrous acid, and would have a sp. gr. about 1.6405. The temperature just capable of effecting this degree of concentration was about 36°, equal an evaporating force of 0.30 inch of mercury. The atmospheric pressure under which the final concentration was effected, was from 28.34 to 28.97 inches of mercury, as I find on reference to my general register.

I have one other experiment; but, as it was conducted in a manner similar to the preceding, it may be unnecessary to enter into detail respecting it: it will, perhaps, be enough, if I give its result in the following table, together with the results of those which I have more fully enlarged upon.

| Experiments. | Temperature at which the concentration was effected. | Evaporating force by which the concentration was effected. | Pressure under which the concentration was effected. | Degree of concentration effected. | |
|---|---|---|---|---|---|
| | | | | Per centage of anhydrous acid. | Specific gravity, at Temp. 60o. |
| | | Inch of Mercury. | Inches of Mercury. | | |
| 1st | 57° | 0.61 | 0.90 | 71.53 | 1.814* |
| 3rd | 48 | 0.46 | 0.90 | 70.69 | 1.8075 |
| 8th | 32 | 0.26 | 0.90 | 67.80 | 1.7762 |
| 2nd | 17 | 0.15 | 29.81 | 26.78 | 1.249 |
| 4th | 48 | 0.46 | 29.30 | 62.77 | 1.7071 |
| 7th | 36 | 0.30 | 28.34 to 28.97 | 58.10 | 1.6405 |
| 9th | 55 | 0.58 | 29.57 | 66.40 | 1.7600 |

From Professor Graham's statements in his

* The specific gravities here given are from the results of experiments of my own, carefully conducted upon the acid whose degree of purity I have described in a note, page 355, in this paper. And, except in the instance of sp. gr. 1.249, a very remarkable coincidence may be observed to exist, between them and the per centages of anhydrous acid, with those given by Dr. Dalton *(New System of Chemical Philosophy, vol.* 1, *part* 2, *page* 404*)*. The per centages given by Dr. Ure in his table *(Chemical Dictionary)* in the same instances appear to be between 2 and 3 too high. The per centage given by Dr. Dalton, in the instance of sp. gr. 1.249, appears to be about 1.8 too low; and that by Dr. Ure, nearly 1 too high.

paper on "*water as a constituent of salts*," published in the Transactions of the Royal Society of Edinburgh, vol. xiii, part 1, and in the London and Edinburgh Philosophical Magazine, for May, 1835, it would be inferred that a low temperature would not be capable of concentrating sulphuric acid to any considerable strength; for, he therein alludes to having observed a close approximation to the sp. gr. 1.78, in concentrating a dilute acid *at a temperature not exceeding* 300°; and he states that in one experiment, a small quantity of dilute acid was found to concentrate down to three atoms of water to one anhydrous acid (=sp. gr. about 1.66,) *at a temperature not exceeding* 212°. My experiments prove that *so low a temperature as* 48°, *and exposure to anhydrous air, are enough to concentrate the acid to the sp. gr.* 1.7071, if sufficient time be allowed; *and a temperature of* 55°, *to the sp. gr.* 1.76.

The results arranged in the table, will, I believe, be found, at least, near approximations to the truth: and, while they point out to us, in seven individual cases, the particular strengths of acid whose attractions for water counterbalance the evaporating force of anhydrous space, under the several circumstances; they also enable us to form

more correct ideas than we could have done without them, of the strengths of acid required to balance the evaporating force of space under other not widely different atmospheric temperatures and pressures, and afford us some information on the extent to which sulphuric acid is a drier of the atmosphere. Was this the whole amount of the information furnished by them, it would not, I trust, be considered too trifling to support me in the propriety of submitting them to the notice of men of science*: but, I feel that they more extensively support me, when I find that reflection upon them enables me to furnish information whereby improvement in the more economically conducting the manufacture of sulphuric acid may hereafter most probably be made.

* Dr. Faraday has remarked (Phil. Magazine, for October, 1833,) that many facts present themselves to observant men, which, though seen by them to be curious, interesting, and new to the world, are not considered worthy of distinct publication: that he has often felt this conclusion to be objectionable; and is convinced that it is better to publish such facts, and even known facts under new forms, provided it be done briefly, clearly, and with no more pretension than the phœnomena fairly deserve.

# DR. DALTON'S TABLE,

### SHOWING THE EXPANSION OF AIR, AND THE ELASTIC FORCE OF AQUEOUS VAPOUR, AT DIFFERENT TEMPERATURES.

| Temp. | Volume of air. | Utmost force of aqueous vapour. | Weight of 100 cubic in. of aqueous vapour. | Temp. | Volume of air. | Utmost force of aqueous vapour. | Weight of 100 cubic in. of aqueous vapour. |
|---|---|---|---|---|---|---|---|
| | | in. of Mer | grain. | | | in. of Mer | grain. |
| 28° | 420 | | | 53° | 501 | .54 | .354 |
| 20 | 428 | | | 54 | 502 | .56 | .366 |
| 10 | 438 | | | 55 | 503 | .58 | .378 |
| 0 | 448 | .08 | | 56 | 504 | .59 | .384 |
| 10 | 458 | .12 | | 57 | 505 | .61 | .396 |
| 20 | 468 | .17 | | 58 | 506 | .62 | .402 |
| 30 | 478 | .24 | | 59 | 507 | .64 | .414 |
| — | — | — | | 60 | 508 | .65 | .420 |
| 32 | 480 | .26 | .178 | 61 | 509 | .67 | .432 |
| 33 | 481 | .27 | .184 | 62 | 510 | .69 | .444 |
| 34 | 482 | .28 | .191 | 63 | 511 | .71 | .456 |
| 35 | 483 | .29 | .197 | 64 | 512 | .73 | .468 |
| 36 | 484 | .30 | .203 | 65 | 513 | .75 | .480 |
| 37 | 485 | .31 | .209 | 66 | 514 | .77 | .492 |
| 38 | 486 | .32 | .216 | 67 | 515 | .80 | .509 |
| 39 | 487 | .33 | .222 | 68 | 516 | .82 | .521 |
| 40 | 488 | .34 | .229 | 69 | 517 | .85 | .539 |
| 41 | 489 | .35 | .235 | 70 | 518 | .87 | .551 |
| 42 | 490 | .37 | .245 | 71 | 519 | .90 | .569 |
| 43 | 491 | .38 | .255 | 72 | 520 | .92 | .580 |
| 44 | 492 | .40 | .267 | 73 | 521 | .95 | .598 |
| 45 | 493 | .41 | .275 | 74 | 522 | .97 | .610 |
| 46 | 494 | .43 | .284 | 75 | 523 | 1.00 | .627 |
| 47 | 495 | .44 | .293 | 76 | 524 | 1.03 | .645 |
| 48 | 496 | .46 | .303 | 77 | 525 | 1.06 | .662 |
| 49 | 497 | .47 | .313 | 78 | 526 | 1.09 | .680 |
| 50 | 498 | .49 | .323 | 79 | 527 | 1.12 | .700 |
| 51 | 499 | .50 | .329 | 80 | 528 | 1.16 | .721 |
| 52 | 500 | .52 | .341 | | | | |

I will now advert to the manufacture of sulphuric acid, and make such reviews of the chemical actions which take place in it, as are required to enable me to show in what respect the improvement I have alluded to is to be made.

It is, I think, universally admitted, that dry nitrous acid gas has not the property of changing dry sulphurous acid gas into sulphuric acid; and that it only has that property when water intervenes. The theory of the production of sulphuric acid being, that nitrous acid gas, sulphurous acid gas, and a little water or aqueous vapour meeting together, a mutual action takes place between the three bodies, and a crystalline substance is formed: this crystalline substance is permanent until brought into contact with more water, either in the liquid or vaporous state: when it has had an opportunity of acquiring sufficient water, it is resolved into sulphuric acid and nitrous gas: the latter, immediately taking to itself more oxygen from the atmospheric air in the interior of the chambers, is reconverted into nitrous acid gas; and this, mingling itself with sulphurous acid gas and water, causes a repetition of the operation just mentioned. In this continuous manner the ordinary process of the manufacture of sulphuric acid is conducted.

Now, the only state of the water with which the greater bulk of the mixed gases in the chambers has the opportunity of coming quickly into contact, is the vaporous state; and when it is considered how little the weight of aqueous vapour is which is capable of existing in a given space, at ordinary atmospheric temperatures, we need not be surprised at the slowness of the process of the manufacture of the acid in question.

At the commencement of the manufacture of the acid, the floors of the chambers are covered either with water or dilute acid; and therefrom arises, into the aerial space, aqueous vapour, as in other ordinary instances of spontaneous evaporation. Supposing the large quantity of mixed sulphurous and nitrous acid gases to seize with avidity upon the whole of the vapour, and make the aerial space anhydrous; this anhydrous space would acquire more vapour from the liquid on the floors, and thereby be the means of transferring more water to the newly formed compound, which must be slowly descending, like a fog, towards the liquid on the floors. It is obvious that the greater the amount of vapour existing in the chambers previously to the commencement of the process, and the more quickly the space can be replenished with vapour as the action of the gases

abstracts it, the more quickly must the newly formed compound be enabled to deposit itself in the liquid on the floors; for, if the compound when newly formed had only a minimum of water, it would be a diffused crystalline body, appearing like a fog; but if it had an opportunity of speedily acquiring more water, it (the fog-like body) would collect into small drops, and descend, like small rain, with greater speed. And, it is requisite that this compound should get deposited as quickly as possible into the liquid on the floors; because it is not till it has become thereby diluted, that it emits its supply of nitrous gas for the continuance of the process.

Some manufacturers of sulphuric acid state that they are able to make more acid from a given weight of sulphur, in a given time, in summer than in winter; but they are not able satisfactorily to account for the difference. I have had the means of fully satisfying myself that such is really the fact; nor is it, indeed, any other than what strict attention to theory would lead us to anticipate. Let us only consider, that in winter the temperature of the external atmosphere, to which the chambers are exposed, is frequently at 32°, and not seldom below that, and that in summer it

often exceeds 80°; and we find that the aerial space of the chambers is capable of receiving from the liquid on the floors four or five times a greater weight of aqueous vapour in summer than in winter, and of transferring it, in a proportionately accelerated rate, to the newly formed combination of gases voracious to receive it. Then, since an abundant supply of aqueous vapour is indispensable to the speedy conversion of sulphurous acid, by nitrous acid, into sulphuric acid, and since the capacity of space for vapour not only increases with an increase of temperature, but even increases in an increasing ratio as the temperature rises, how can it be otherwise than extremely evident that as much sulphur cannot be converted into sulphuric acid, in the same chamber room, and in a given time, in winter as in summer? When the attempt to effect such an object is made, the consequence is, that large portions of the gases pass through the whole range of chambers, and at length escape by the outlet into the external atmosphere, without being condensed; and, indeed, as sulphuric acid chambers are usually managed, a great amount of the gases must in winter be lost in this manner; for, when the temperature of the atmosphere is low, the operator finds a difficulty in keeping the temperature of

the furnace in which the sulphur is burnt, sufficiently high to keep up the combustion, when he attempts to burn only a minimum of sulphur; and, not having (in many instances) other means of preserving the requisite temperature, he is reluctantly urged to burn more sulphur than circumstances render him capable of converting into, and collecting in the state of, sulphuric acid.

So far, then, I have shown that when the floors of the chambers are covered only with water, or *dilute* acid, there is substantial reason why less sulphuric acid should be collected from a given quantity of sulphur in cold weather than in warm: and, when we take into consideration that the acid on the floors of the chambers is seldom very dilute; but that it is frequently allowed to be of such strength as to have the sp. gr. 1.45 or 1.50, we find that there is additional reason why cold weather should be objectionable. On reference to the table of the results of my experiments, we see that at the temperature of 36°, and at the pressure there stated, the acid was only capable of being concentrated till its per centage was 58.1, =sp. gr. 1.6405, and we may conceive that if the evaporating force of space at the temperature of 36°, was just balanced by the attraction of acid

sp. gr. 1.6405, the rate of evaporation from acid sp. gr. 1.45 or 1.50 at the same temperature, must be but very slow, and more especially so at temperatures below 36°. Sometimes in severe winter weather the temperature of the chambers is probably as low as 17°; and my experiments show that when the temperature is only 17°, and the pressure about 29.8 inches of mercury, the acid can only be concentrated so far as to have the per centage 26.78, =sp. gr. about 1.249; the fact, therefore, is, that in a case of so low a temperature as 17°, no evaporation whatever could take place from the acid, if its sp. gr. was greater than 1.249; and, consequently, in such a case, the process of the manufacture of sulphuric acid must be entirely stopped, was it not that aqueous vapour was supplied from some other source. Indeed, *some* vapour always is supplied otherwise than from the acid on the floors: some enters the chambers with the air by which the combustion is supported; but, when the temperature of that air is so low as 17°, or 20°, or 30°, the weight of the vapour admitted along with it is too trifling to be of much avail in an instance of so great a demand. It has for some time been a practice among some manufacturers of the acid, to turn steam, issuing from a pipe connected with a vessel of boiling

water, into the chambers*: this must have a particularly beneficial effect, when the temperature of the chambers would otherwise have been as low as I have just alluded to, but it has also disadvantages: its beneficial effect cannot last much longer than during the time the steam is allowed to enter the chambers; and it is imprudent to allow it to do so long, because the great cooling power of the chambers causes the steam to condense nearly as quickly as it enters; and by continuing to admit it, the acid on the floors would soon become much diluted; the consequence of which would be, that the manufacturer would have

* Though steam is sometimes thus used, it is not because those who use it have a correct knowledge of the great importance of the continual generation and existence of steam (in the scientific acceptation of the term, invisible vapour) in the chambers. They use it, from the understanding that it—steam of 212°, or thereabout—must necessarily be condensed on entering the cold chambers; and in the resulting water falling as rain or fog, the gases readily meet with the water dispersed for their action—the condensed steam, therefore, carrying the sulphuric acid down along with it;—nor do they seem to be aware of the fact, that if the temperature of the interior of the chambers was so high as to hold (supposing the absence of acid and the gases) in an uncondensed and invisible state the steam admitted, that even then the gases would, if admitted, supply themselves from that steam with the requisite water, and that strong liquid acid would fall, though the temperature might be great enough to retain pure water in the state of invisible steam.

to be at much additional expense in concentrating it when removed fom the chambers.

Having explained my views to a friend, he, during the last winter, and when his chambers were not working well in consequence of the severe cold, had a vessel of water so placed in the furnace as that the hot gases were enabled to convey along with them into the chambers a comparatively large quantity of vapour: and this plan cannot but have been attended with some benefit; yet, the benefit must have been highly inadequate, because, as in the case of steam turned in from a pipe, the vapour thus admitted would be speedily condensed by the cold chambers.

It is quite evident that the great desideratum is to be enabled to give the whole interior of the chambers, at all times, a temperature not less than that of summer; nor do I think that a doubt can reasonably be entertained that a temperature considerably higher than the maximum temperature of summer would be attended with a corresponding beneficial effect. Consequently, what I suggest as an improvement in the working of sulphuric acid chambers, is that leaden pipes should be caused so to pass through the interior of the chambers as that when the steam of boiling water

is allowed to pass through them they will communicate warmth, or even hotness (if the same should upon trial be found to give additional benefit), to the whole internal aerial space of the chambers: and, it does not seem to be of much consequence whether the pipes be laid through the acid on the floors, or only through the space immediately above that liquid;* for, in either case, the aerial space would become heated. Such a contrivance would be of benefit in two ways;—it would heat and supply the aerial space with vapour, and would, inevitably, at the same time, be considerably concentrating, instead of diluting, the liquid acid on the floors.†

It may be said, that in the foregoing remarks I have not taken into consideration that the heat, conveyed into the chambers from the furnace

* Perhaps the greatest advantage would be obtained if the pipes were laid both through the liquid and through the space above the liquid.

† It is advisable, that in erecting chambers attention should be given to their form: those having the least cooling surface, in relation to their internal capacity, being the most preferable. If the form of a cube be departed from, it should be in the depth: indeed, from what I have said (page 383) regarding the necessity of the quickly depositing of the crystalline substance, it may be inferred that there is chemical reason why they should be less deep than cubical, independently of the fact that in such case they will more firmly support themselves.

where the sulphur is burning, must prevent the interior of the chambers from ever having so low a temperature as the external atmosphere in winter: to which I must reply, that towards the extremity of a range of several chambers there will not, I think, be found *much* difference between the internal and the external temperature: but, even admitting that a considerable difference exists between the internal and the external temperature throughout the whole range, let the argument be extended to summer temperature as well as to winter, and the result will give greater support to my views; for, then, for the same reason, it must be allowed that the internal temperature must be much higher than the external temperature, in the shade, (80° for instance, as before mentioned); and to this I may add that as the chambers are generally exposed to the direct heating influence of the solar rays, the internal temperature must, from that direct action of solar heat alone, be very much higher than the temperature in the shade without. And, as the capacity of space for vapour increases in an *increasing* ratio as the temperature rises, the very much greater speed with which the aerial space is supplied with vapour in summer than in winter is undeniable.

Bolton-le-Moors, May 28th, 1838.

# APPENDIX

## TO THE FOREGOING PAPER.

I perceive, under the head Sulphuric Acid, in the last of the monthly parts of Dr. Ure's "*Dictionary of Arts, Manufactures, and Mines,*" which is just turned out from the press, that an experiment has been made by M. Clement-Desormes, expressly to ascertain the effect of an elevated temperature in causing the process of the formation of sulphuric acid to go on freely; the result of which showed the beneficial application of the temperature of 100°, in promoting the active agency of the aqueous vapour upon the gases. It is highly gratifying to find that my anticipations, arrived at from theoretical reasoning, are in such a satisfactory manner corroborated by direct experiment.

From the conclusion of this experiment of M. Clement-Desormes, Dr. Ure seems to recommend maintaining the temperature of sulphuric acid chambers at 100°:—this he would do by the admission of a jet of steam; it being discharged

from a high pressure boiler loaded with forty pounds upon the square inch. He says that it serves, by powerful agitation, not only to mix the different gaseous molecules intimately together, but to impel them against each other, and thus bring them within the sphere of their mutual chemical attraction. The mechanical commotion which must be produced, by the sudden freedom from confinement of a body having the elastic force of steam under a pressure of forty pounds upon the square inch, would, I admit, be advantageous if sufficient agitation of the gaseous molecules was not derivable from another source: but, when we consider the comparatively enormous bulk of the aeriform bodies which has to be condensed into one cubic inch in the formation of a cubic inch of sulphuric acid, or of the crystalline compound produced from sulphurous acid, nitrous acid, and a minimum of water, surely our imagination will not allow us to suppose that the agitation which takes place, in tending to restore the equilibrium disturbed by such condensation, is not sufficient to intermix and diffuse amongst each other the several kinds of gaseous molecules, leaving out of consideration the general law of the diffusion of aeriform bodies experimentally illustrated by Dr. Dalton, in the Manchester Memoirs,

Vol. 1, second series: and, from the very active manner in which combination of the gases is known to take place when plenty of aqueous vapour is present, I cannot conceive that any additional impulse is required. Dr. Ure admits that the chemical agency of steam is more important than its mechanical agency; and, in this I fully agree with him: but, of course, for the reason given in my foregoing paper, I do not concur with him in thinking it advisable that the steam should be furnished by a jet from a boiler, but that it is preferable for it to be derived from the liquid on the floors of the chambers. Not admitting the necessity of its mechanical agency, high pressure steam is essentially no more beneficial than low pressure steam; because, from the conversion of it to the liquid state, it is not capable of communicating to the interior of the chambers any higher a temperature than low pressure steam, since the same *weight* of steam, whether under high or low pressure, contains exactly the same quantity of caloric.

H. H. WATSON.

Bolton, April 1st, 1839.

ON THE

# ROHAN POTATOE.

By DOMINIQUE ALBERT, LL.D.

Communicated by Mr. JOHN DAVIES, M. W. S. (Read March 5th, 1839.)

The Prince de Rohan, a relative of the Royal Family of France, having retired from the court since the accession of his kinsman, Louis Philippe, turned his attention to the improvement of agricultural industry on his estate, situated in the Jura, on the limits of France and Switzerland: there the Prince produced for the first time, in 1831, a potatoe extraordinary as to size and weight. By what means or process this monstrous tubercula made its appearance, remains yet a secret beyond the gardens of the Prince; however, the author of this interesting natural production, has given some of its seed to several of his friends, with the following particulars :—

Light soil, first opened to the depth of about one foot and a-half, is well manured; the animal black, or the animalized black, seems to answer its purpose the best. Each tubercula is cut into as many sets as it represents sound eyes; the sets placed at thirty inches one from another, are planted in March, and taken out at the end of November, if prudence does not require it sooner. In France the plant appears at the beginning of May; and for nearly a month the soil must be heaped round it, to strengthen the stalk, which attains the height of seven, and often eight feet. To get its fruits of the largest size possible, it is recommended to prop the stalks with sticks of six or seven feet in length, and to fix horizontal sticks so as to enframe the stalks of it, at the height of about three feet and six feet. The largest tubercula of this species produced in France, weighed 15℔s. 2ozs.; and the greatest produce from one set was 27℔s. The small ones, and those of a middle size, are generally round. Those above 2℔s. are a sort of ludi naturæ. The largest are long shaped; their external appearance is rough, and the eyes lie deep in, with a purple tinge. Thinking that the cultivation of this peculiar kind of vegetable might benefit this country, I succeeded in importing about a dozen of good-sized tuberculas,

by the kindness of one of the Prince's friends; for this seed has not yet been sold in France. I received them in November, 1836; divided them amongst my agricultural friends at Cadishead, and the environs, with a copy of the method for their culture, and reserved one for my own experiments. It weighed about 2tbs.; gave seventeen sets, and produced 185tbs; affording an average of 11tbs. per set.

My heaviest was of 3½tbs. The manure I made use of, was of an animal nature, being refuse from my manufactory of prussiate of potash; I used also the propping sticks. Each stalk had many buds, but, with little exception the buds fell off before opening; I observed, however, a few very small white flowers, which were closed about half an hour after sunset. Nothing like a fruit was ever produced from them. The potatoes, when dug out, were heaped in a close perpendicular pillar round the stalk, and the top ones were so near the surface of the soil, that many were half uncovered. The horizontal roots, which extend from 25 to 30 inches, are of the thickness of a good quill, but bear no fruit.

In 1838 I made my second experiment; but the

animal manure having been for more than a year exposed in the open air, I thought to revive its qualities by sprinkling it with a solution of nitre. The season, unfavourable in general, limited my crop to 8½lbs. per set; but I got larger tuberculas than in the preceding year, and my finest weighed 5lbs. 10ozs. They are generally heavier than their volume seems to show; and, from an experiment I made upon one potatoe, they lose one-ninth in weight for a month after they have left the ground. The same tried upon a good pink-eye potatoe did not give me more than a diminution of one-twelfth.

I must mention, that, considering the recommendation of using sticks might prevent this tubercula being cultivated upon a large scale, I dispensed with the use of this article, for my last year's crop, and left the plant to take its natural direction. The result showed that I had not left out the *sine qua non.*

When boiled, this potatoe is rather yellow than white; not so mealy as other good species, but more tasteful. I should recommend to slice the larger ones, when employed for the table. In France, where the culinary art seldom allows

a potatoe to appear in its natural nudity, the Rohan potatoe, on account of its taste, may have more admirers than in England; but, considered only as a most prolific cattle food, it certainly deserves the attention of British agriculturists.

I ascertained, by scraping and washing out the feualo, that the Rohan contained one-tenth more farina than the Radical, which I consider one of the best sorts.

PROCESS OF

# CARBONIZING TURF

WITHOUT CLOSE VESSELS,

THE PEAT FURNISHING ITS OWN CALORIC, WITHOUT PRODUCING ASHES.

By DOMINIQUE ALBERT, LL.D.

Communicated by Mr. JOHN DAVIES, M.W.S. (Read March 5th, 1839.)

When, in 1835, I built my present works at Cadishead, I was chiefly induced to choose the place on account of the proximity of both turbaries, Chat Moss and Barton Moss, having previously ascertained that I could make with turf as good charcoal as with wood.

As the charcoal I wanted was for some chemical purpose other than to be used as fuel, the first condition of the carbonization was, that it should produce a vegetable black, free from the mineral substance mixed with it, as is always

the case when turf is carbonized in Ireland, to supply the hearths of some country smithies. I began, then, by submitting the turf to a dry distillation in iron retorts, five feet deep to four feet diameter, covered with strong sheet iron caps, to which I adapted cast iron pipes. I soon found, however, that the quantity of auxiliary mineral fuel required to burn the turf, owing to the distance of seven miles from the nearest pits, rendered this method too expensive to be continued.

I expected that the acid would compensate for the price of the coal, but I could never get it above two or three degrees; besides, the pyrolignous alcohol diluted in the acid existed in a very small proportion. The tar, which was comparatively abundant, contained the greater part of the spirit, but the low price of tars in general offered me no encouragement to proceed.

I knew, by the discoveries made by my countryman, Mr. Merle, in 1834 and 1835, that certain species of turfs gave a richer and superior gas than either coals or oils, and I convinced myself that the peats in my neighbourhood were of an excellent quality for such a purpose, but I

did not feel inclined to set up any apparatuses to save that produce, so I turned all my attention to find a cheaper mode of producing pure charcoal.

I had latterly observed the Irish in their process, which consists of setting fire to a few turf cakes placed on the ground, so as to let the air play between. As soon as these cakes are burning, they heap round and above other cakes, which very soon ignite also. They continue to feed thus this heap of fire, till it reaches about five feet in height, and six or seven at its base. They let it burn until the whole appears in a complete glow, when they cover it with large wet sods, either of soil and grass or heath sods, from the surface of moss land. This careless, but cheap and easy manner, causes the charcoal to be mixed with a quantity of uncarbonized vegetable, marl, sand, stones, and a notable proportion of ashes, all matters which do not affect the iron jobs with which they come in contact.

The Dutch I saw many years ago, carbonizing peat for domestic purposes, in small conical furnaces, as common with them in the country places as the bread ovens are here. They light the turf from below; and, when the combustion is nearly

completed, they close the top and bottom. Their method, though superior to the Irish, and well adapted to their object, is neither as complete, nor does it give so pure an article as I wished; besides, I found its application almost impossible on a large scale.

Amongst the different plans and instructions I consulted to assist my experiments, I gave the preference to a large round perpendicular furnace, in which, according to Dumas, (Chemistry applied to the Arts) Mr. La Chabeaussiere distils wood.

After having studied what modifications were necessary to render Mr. La Chabeaussiere's furnace useful for peat's carbonization, without saving either gas or liquids, I constructed the following kiln:—On a solid soil, I made an excavation from ten to twelve feet wide at the top, nine feet deep, and nine in diameter at the bottom, which I covered with a dry brick floor, that had a convexity of six inches. I lined this hole round with a dry brick wall, in the way of a common pump pit. At four equal distances at the bottom of the round wall, I opened an air hole of about four inches square, and continued it in the form of a

narrow chimney outside the wall, to the height of about six feet, when I prolonged it about six feet more, but in an horizontal direction. For the top of this kiln I had a sheet iron cover made, a few inches wider than the diameter of the brick work, of a convexity of two feet, with a round hole or chimney in the centre, one foot high, and nine inches diameter, provided with a cover and handle similar to that of a canister, and at a foot from the extremity of the large cover, are cut out four auxiliary chimneys, at equal distances one from the other, with a four inch diameter. Four strong iron rings are fixed to the cover to receive the hooks of a chain, which, by means of a double purchase, raises or lowers the cover.

When this furnace, says Dumas, is filled with wood, the cover is lowered down, and some fire-brands are precipitated through the central chimney to the bottom of the kiln; the wood being placed so as to leave a sort of funnel open. By means of the four blowing air-holes the fire is very soon spread in all directions, and its progress is to be regulated by shutting or opening the smoke and air holes, according to the direction of the wind.

These rules, which no doubt did answer when

wood was to be distilled, were inefficient when applied to the carbonization of peat; but by dint of trials and patience, I succeeded beyond my utmost expectations, upon the following plan:

I make two tunnels of inch board, nine feet high and eight inches square, with some hand-holes from distance to distance. These tunnels I place in the kiln along the side, in order that the bottom end may correspond with one of the four air-holes; one of my workmen descends then to the floor of the furnace, and forms an ærated bed with peat, by setting the cakes upright, with their tops inclined one towards another, so as to create a good draft, which must, as much as possible, run in the direction of both air holes where the tunnels are standing. It is necessary for this operation that the cakes be entire and dry, as pieces would intercept the air, and a wet cake would paralyse the action of the fire. After the setting of this bed, the peat is thrown down upon it, and left in the natural confusion of its fall, only it is required that a man places round the tunnels the turf cakes in regular order, to build like a chimney round these moveable tubes. When the kiln is filled and heaped up about three feet above the level of the hole, the tunnels are

drawn out by means of their hand-holes, and leave two square passages from top to bottom. In these temporary chimneys, a few incandescent peat cakes are thrown, and on these some broken pieces of turf, till the passages are filled; but as the air plays more freely through these former chimneys, some barrowfulls of peat crumbs will shut the too wide pores, which places are easily seen by the greater volume of smoke escaping from them. The kiln left open to facilitate a more general conflagration, is not covered before the heap of turf cakes has sunk to the level of the brick work. In this state, the cover is let down, and some soil is brought round its border to intercept the escape of smoke. In this stage of carbonization, all the air-holes with the large and small chimneys are open.

As soon as the fire is perceived through either of the small chimneys corresponding with the passages where the fire has been lighted, the horizontal mouth of the same air hole is to be shut with a piece of brick and some marl, and the others are to be successively stopped in the same way, the moment the redness of the fire can be distinguished. If there remains any doubt of the perfection of the operation, a pole about fourteen

feet long should be thrust through the hole where the carbonization appears incomplete, and by thus gauging to the bottom of the furnace, you will immediately be aware of the state of the charcoal, which you can remedy instantly, by opening the air hole opposite the place examined.

When the smoke begins to abate, you place the cover on the central chimney, but so as to shut only the half of the aperture, taking care at the same time to direct the open part of the cover towards that part of the kiln, which you might consider not so perfect as the remainder. At last, when the eruption of smoke has ceased, you shut all chimneys immediately, and the operation is at an end. It requires generally twenty-four hours to complete the carbonization of one furnace, and sixty hours, for carbonization and cooling of the charcoal. A kiln of these dimensions can receive between three and four one-horse-loads of peat, of about fourteen hundred weight.

There are three kinds of peat. The white, or top of the moss land, is the lightest, and consequently the worst; it is sold from four to five shillings the load. The brown, which comes

from the second stratum, is much better, being more compact, and sells at five shillings and sixpence per load.. The black, or best quality, sometimes called iron turf, is very hard and heavy: it gives an intense and sharp heat; produces a thick black smoke, with strong and unpleasant smell; it burns slowly, and is bought at six shillings. The incineration of the black turf leaves heavy reddish ashes, whilst those of white turf are of a sulphur yellow, and those of the brown have often a sort of orange tinge.

The peat ashes which owe their alkaline quality chiefly to the presence of lime, are considered a good manure for grass and clover, and used as such in the north of France and in Belgium. March and April are the best months to use them. They are generally sown during damp weather, and will have a good effect used with any plant, at its first appearance above ground. I tried them last year with pease and other vegetables, and perceived in one instance, that the use of them cleared the cabbage plants of the insects that were devouring them.

In order to get the kiln to act more regularly, it is well to carbonize each sort of peat separately.

I have at present, four furnaces or kilns, at work; they are constructed between two rails, on which I have built a moveable frame, with a roof covered with a tarpauling. This skeleton of a house answers two purposes, namely, it enables the men to fill and empty the kilns in all kinds of weather, and affords to the whole line the use of the double purchase to wind up the heavy iron covers.

The white turf gives a fourth of its weight of charcoal, the brown a third, and the black one-half.

The nature of charcoal from peat, is a great deal less pyrophoric than that of wood charcoal; and during the four years that I have had always large quantities in the interior of my works, I have not had a single instance of a spontaneous ignition, whilst I had two accidents of this nature, with wood charcoal, in the short space of six weeks.

# AN ESSAY

ON

# THE ROMAN ROAD

IN

## THE VICINITY OF BURY,

LANCASHIRE.

By. Mr. JOHN JUST,
*Corresponding Member of the Society.*

Read April 2d, 1839.

What we see, and hear, and read, and experience, constitutes the sum total of our knowledge. Things which have been, and now are, we can compare; and the results of such comparisons we can store up as treasures for the mind, out of which our memories can draw whatever currency our intercourse with society demands, either for our own credit, or for the benefit and assistance of others. Of the long past, however, it is very little that we can know: the line which connects it with the present, becomes fainter and fainter as it recedes, until it

loses itself in the far distant horizon behind us. In the physical world things only *before* us we can see; in the intellectual we note chiefly what is *behind* us; the one is all *pro*spective, the other *retro*spective. But retrospective impressions are weak in proportion to the remoteness of time, inasmuch as commonly every additional impression which the ever striking present presents us, tends to obliterate what has preceded, until numbers of impressions are defaced, and others so faint that it is difficult to trace the outline, and recollect what they once were. Time tries all things. It levels mountains as it rolls over the globe; it crumbles pyramids as it wipes off the dust from their surface, every year that its wings sweep over them. Neither works of nature nor of art escape it. They become at length defunct; and while it entombs their remains it spares not their histories, but either leaves their memories unsculptured, or fritters away the ciphers o'er their graves, till they become illegible and perish. "*Sic transit gloria mundi.*"

It is said that there is no rule without an exception, and that exception proves the rule. If, then, the saying be true, and what has just been read be the general rule, there will be an excep-

tion. All will not be obliterated. Fragments of antiquity will remain with fragments of their histories, to show what has been, and to tell their uses and purposes. Where arts and civilization have existed, a few scattered and imperfect specimens will be found to amuse and edify remote posterity, a tincture will diffuse itself to ameliorate the character of a long series of ages and generations still to be born.

But this is not the only way in which a civilized people confers benefits upon mankind; they leave us correct histories of their own internal affairs, and they mingle with them all external ones which arise out of their foreign policy as regards other nations less civilized than themselves. To Greece we owe all we know of the ancient histories of the semi-barbarous East; and in the pages of imperial Rome we read most of what we know of ancient Gaul, Kelt, or Kymerian. It is hence chiefly, in connexion with what remains of art, that we derive the materials for constructing the scanty fabric of the ancient history of our own country, now so superior in every respect to the haughty pretensions of the dictators and conquerors of the best part of the world then known.

We all know very well how the eagle of that empire, perching upon the palaces and temples of the eternal city, spread out its wings over Europe into Asia, from the western shores of our own Britain even to the Indus and central Asia; and that for four hundred years its emblem on the banners of its legions was borne victorious from east to west, from south to north, over the major part of this island; and we likewise know, wherever Romans trod they left not their footsteps in the perishable sand, but in their march, reared up monuments of labour almost as imperishable as their glory; and though the greatness of Roman power has vanished, like all former greatness, yet its evident remains are still scattered over the lands which formerly beheld it, and added to its triumphs. And as the language of these masters of mankind—with which they dictated to the nations as to their slaves, and which far as possible, and almost beyond what is probable, they imposed everywhere—is that language which either formed the foundation or the corner stone of all our education in youth, and forms also the basis of many a language which we may have added as accomplishments since, as well as constitutes no inconsiderable portion of the polished and flexible part of our own, we cannot

well overlook any traces of a people who have thus become so interesting and useful to us, which may have survived the physical and artificial changes of fourteen centuries, and still be lingering in our very neighbourhood; and over which we may be, and undoubtedly have been, many times, led, either by the avocations of business, or the promptings of pleasure.

The Romans first entered that part of Britain which now comprises the county of Lancaster, about the year 79. During the preceding summer Agricola, their general, had reduced the Ordovices, or the inhabitants on the Dee, in Cheshire and North Wales; and in the summer of the year just mentioned, proceeded with his conquests northward to the Sistuntii, who inhabited Lancashire and the southern portion of Westmorland. As one object of this celebrated commander was to secure to the empire the countries which he subdued, his successes were followed up by the erection of such works as experience had shown to be capable of keeping the inhabitants under complete subjection. Tacitus informs us that Agricola built forts and placed garrisons within them throughout this district, which then was woody. The discipline of the

Roman legions was kept up by constant labour; and as there needed communications between the several forts and garrisons which he erected and stationed, he, according to the Roman custom, then commenced the military ways which connect them. The British towns within the Sistuntian territory had, doubtlessly, their roads between them; but such were not direct enough, nor suited from their kind and uses, for the purposes of warfare. The ways, therefore, which had been brought up to Deva or Chester, the preceding year, were extended, the woods cut through, and the principal forts erected within them, thus connected with those to the southward as well as one with another; and these military ways served at once for the conveyance of baggage and military stores, and for ramparts, to protect the soldiers during their marches. The ways averaged seven yards in width, from one to one and a-half yard in elevation. Where the ground was lowest, the agger was generally elevated the highest; and where the the ground was highest, the agger was lowest, being more calculated for giving the soldiery an advantage in case of attack during their marches, than merely for dryness and durability, as the historian of Manchester supposes. Their direction was in a straight line, laid out with the

nicest discrimination and knowledge of the country, *upon the highest ground*, and their surfaces were paved with large stones, to give firmness to the footing of the cavalry and beasts of burden as they passed, and to resist as little as possible the motion of the wheels of their waggons and vehicles, in which they transported from place to place their baggage. It is owing to this peculiarity of construction, that these mountainous roads may still be seen, as ridges intersecting parts of the country, or their remains traced out in elevations which they have left until the present day.

If Tacitus' account of Agricola's conquests in Britain, leads us to infer that Agricola constructed a military road throughout Lancashire, from the south of it to the north, a later account of the stations in Lancashire, either established by him or by his successors, is given us by another Roman, Antoninus, in his Itinerary of the kingdom. His Tenth Iter is considered to have been southward, from the county of Cumberland, through a part of Westmorland, and thence, through Lancashire, to this place, Manchester. His statement, according to the copies which have reached us, stands thus: From Alione to Galacum, 19 miles; to Bremetonacæ,

27 miles; to Coccium 20 miles; to Mancunium, 17 miles; beginning at Brougham castle, according to some antiquaries, or at Whitley castle, according to Camden, and ending here. The distance, as given above, is 83 miles, and making the necessary allowance between the straight line of the Romans and the winding one of the present road from Penrith to Manchester, seems to be tolerably correct. The intermediate distances, however, are, if the intermediate stations be the same as Antonine visited, obviously incorrect. Supposing with Dr. Whitaker, Galacum to be the station at Boroughbridge, and Overborough, as is now generally agreed upon, to be Bremetonacæ, the distance between the two, as given by Antonine, and as they are separated at present, far from corresponds. Again, the distance between Bremetonacæ Overborough, and Coccium or Ribchester, as far exceeds what Antonine gives as the other exceeds the real distance. Much more is his statement inaccurate if Coccium be near Blackrode, where the Manchester historian would fix it. Besides, from Ribchester to Manchester is much beyond 17 Roman miles; and if we obviate this error by stationing Coccium at Blackrode, we are no nearer, because we only increase the error elsewhere. There hence appears to be

an error in some of the particular distances, as given by Antonine, though the general distance may be nearly, if not altogether, correct. Now, not knowing the exact distances between Brougham or Whitley castles and Boroughbridge, nor being acquainted with any remains between them, I cannot say whether the error may have commenced there; but having inspected the remains at Boroughbridge, and knowing the distance thence to Overborough, I can take upon me to state, that the 19 miles written between Alione and Galacum to be about the exact distance, in Roman miles, between Boroughbridge and Overborough. Besides, as far as I can judge from a survey of the Roman road in the neighbourhood of Overborough towards Ribchester, and likewise from what I have seen of its remains in the neighbourhood of Ribchester, as well as by admeasurement on good maps, by transferring the 27 miles between Galacum and Bremetonacœ to the distance between Bremetonacœ and Coccium, we shall not fall far short of the real distance. But whether, by transferring 20 miles as the distance between Coccium and Mancunium, we should at all approximate to the real distance between Ribchester and Manchester, persons who are better acquainted with the localities of

the neighbourhood than myself can best judge, though, on the maps, it appears to be about the third of a degree.

Besides the Itinerary of Antonine, there is another account of the Roman stations and roads in Britain, compiled by Richard of Cirencester; whether there have been authentic documents for the compilation or not, it is not at present our object to inquire. However, it may not be amiss to quote the parallel account which he gives in his 10th Iter the latter part of which stands thus—"From Lugaballa to Brocavonacis 22 miles,—from Brocavonacis to Alauna—from Alauna to Coccium—from Coccium to Mancunium 18 miles." Dr. Stukely refers Brocavonacis to Brougham, and the Manchester historian brings the road of Richard along the present line from Penrith to Lancaster, which he asserts to be the just mentioned Alauna. Thence he follows the present road through Preston, Chorley, &c., until he comes to about 18 Roman miles from Manchester, to Blackrode, which is his Coccium. Now there is some singularity in Richards's 10th Iter being defective in distances just where the parallel in Antonine's is erroneous, not to mention Mr. Whitaker and himself both over-

Watling Street
Watling Street
Gravelly
Open Moor
Agger elevated
nearly perfect
Bury Road
Heyts Barn

looking and omitting a station Concanguim through which the Iter would pass had it been in that direction—or had not the Iter of Richard itself been suspicious in that part of it.

Having so far opened up the subject, we will now proceed to an account of the remains of the Roman road in the neighbourhood of Bury. From almost constant occupation of time, I have not yet had any opportunity of searching for remains between Manchester and the river Irwell in Radcliffe. At Radcliffe then we will commence. A little below the junction of the Roach and the Irwell, near the print works laid out on the sketch, the Roman road crossed the river; it then passed across the holm grounds belonging to Radcliffe Tower, which is about 150 yards to the right, passed through the print works now occupied by Mr. James Hutchinson and Sons, to the Bolton and Bury canal, the $10\frac{3}{4}$ mile stone on the bank of which stands on the very line. On the grounds so far, not the slightest trace is to be seen, but as the ground henceforward rises, a slight elevation is discernible, with a mixture of gravel in the ploughed grounds, until the line crosses Caw Brook; there a few yards of the agger remain of considerable height, showing

distinctly the width and form of the road. Slight elevations and slight admixtures of gravel with the soil mark the line thence until we arrive at Spen Moor; there the remains are very evident; and in the field next to the Bolton and Bury New Road, the agger runs boldly across, having suffered little from cultivation except the removal of the stratum of stones. Continuing the same straight line northward, past Joseph-street, we discern near the fences, close to Starling, traces of the agger. The road then falls in with the Lower Croft-road, remains of which may be seen on the Cockey Moor side, and passes through a garden and under a cottage at the angle of the present road, along the meadow beyond, where the line keeps a considerable elevation to the brook and lodge of the Lower Croft print works. In the corner of the field beyond, may be seen considerable remains, as well as near the fence on the opposite side. Again, in the same straight line in the fold of Meadow Croft, remains are visible, as likewise in the corner of the ground of the second field beyond the farm and premises; thence along till we climb the high ground to Heyts Barn, about 40 yards east of which a long agger points out the direction, and following the line as in the accompanying sketch, remains may be traced, till

the road falls in with that which passes through Offyside, and which retains the name of Watling-street until this day. Watling-street, or Raikes as it was also called, keeps an almost undeviating straight line for about a mile, until it reaches the Bull's Head Inn, towards Edgworth.

So far extends the sketch of the line and remains of the Roman road which accompany this paper, and which is intended to illustrate the preceding account, as well as to be a guide for any future investigator. Mere verbal accounts are of little use as directions, as I have found; besides there are oftentimes discrepancies which are apt to perplex and mislead. I now will give what corroborating testimony I have been able to pick up by inquiries, during my researches. They are traditionary in some instances, and therefore not wholly correct, for tradition, though originally truth, blends error, and exaggerations, and extraneous facts with it. First, then, when enquiring if any account of the line of the road had been preserved in Radcliffe, I was answered there was one in the plan of the print works occupied by Mr. James Hutchinson and Sons. I applied to one of the young gentlemen engaged in the works, and was very politely allowed to examine the plan.

A dotted line, with "Roman Road" written beside it, ran across the plan exactly through the lodges and under the building, as I had traced the line, and as it is laid down in the sketch. When the Bolton and Bury New road was being made, Mr. John Hall, a gentleman curious in collecting specimens of minerals, and investigating the nature and order of the strata in the coal districts around, observing large stones and much gravel removed from that portion where it crosses the Roman line, was informed that such were the remains of the Roman road, which ran along there. Next is Joseph Street, the name of a Farm through which the line runs. But whether the name "Street" has been given to the farm from the occupiers, or the occupiers have taken their name from the farm, is quite uncertain, as, when I asked for the name of the place, I was answered Joseph Street; and when I asked for the name of the family, I was answered Joseph Street; and when I asked whether such was the name of both, I was answered "yah." The first time I traced out the remains of the Roman road near Meadow Croft, a young man, seeing me with a book in my hand, into which I inserted remarks with a pencil as I went along, followed me and the gentleman who accompanied me, and after ascertaining that we

were neither surveying for a rail-road line, nor for levying any rate, but merely for a road that had been, he told us "Then owd felly 's reet, for he used to sey ot Pack Horses com throo't fowt formerly." And who is the old man? we inquired. "Whoy he 's me feyther, an' it wur his feyther, that 's my gronfeyther, ot towd him horses com atween Blackburn and Manchester." And during the last fortnight I was informed by an old man at Meadow Croft, that in the time of his father, many portions of the agger of the Roman road were carted away; the stones for draining the meadow below, near the brook; and the gravel to the road which passes the premises. Likewise he said that he had been told, that that road was the oldest one in the country; that it came along by the Heyts in Offyside, went through Starling and crossed the ford of the Irwell, a little below the meeting of the waters of the Roach. To repeated questions what was the name of the road through Offyside, I was answered "Wadling Street, it 's coen Street, fur it wur paved formerly."

Such are the scanty materials of the information which I have to lay before you at present, little, indeed, in comparison of what remains to be

gathered from this Iter, but which probably I may resume when leisure may permit. The confusion of the intermediate distances between the stations upon it, occasioned most likely by an error of some transcriber, has rendered the determination of the localities one of great difficulty. Whether the error now alluded to be confined solely to distances, or also to the names of the stations themselves, it may perhaps be presumptuous to hazard an opinion. Only it was a rule with the great Camden to seek for some similarity in sound in the modern names of places, or of the rivers on which they stood, with the sound of the Roman names, which he considered strong circumstantial evidence. And the authority of the father of Roman antiquities is not altogether to be despised, though he may have been laughed at for seeking the remains of Coccium upon Cockey Moor. Supposing then there be an error of the transcriber in names as well as the distances of Antonine's 10th Iter, may not the Station at Boroughbridge be the Alione of the text, for it is situated on the Lune, formerly written Lon. Overborough would thus become the site of Galacum, and it too is situated on the Leck-brook, formerly written Lac. Bremetonacæ would hence have to be removed to its belong-

ance elsewhere, and might be fixed at Brougham castle, and it would thus correspond with the Brocavonacis of Richard, which he may have so written from some other copy, or from mistake. This is but conjecture, and would require more extensive acquaintance with the line of the Roman road and the intermediate distances than I yet possess, to merit any consideration of importance. To whatever further extent I may carry sketches and researches, if they merit any notice from this Society they will be at its service whenever called for.

Rutland Arms, Bakewell,
April 2nd, 1839.

REMARKS

ON THE

# COAL DISTRICT

OF

# SOUTH LANCASHIRE.

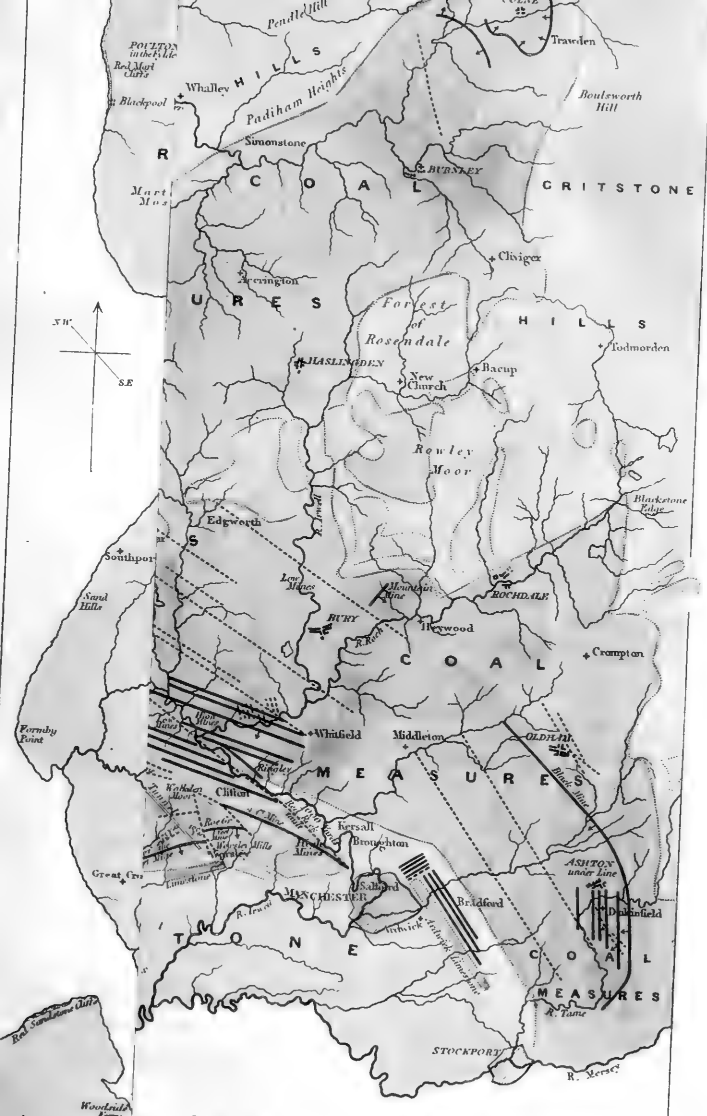
By JAMES HEYWOOD, F.R.S., F.G.S.

(Read December 29th, 1837.)

CARBONIFEROUS rocks have long formed an interesting subject of mining investigation in the county of Lancaster, and facts relating to the Geology of this district are continually discovered, by the researches of mining industry, and by the observations of local inquirers.

Gritstone hills compose the Eastern boundary of the Lancashire coal district, separating the coal fields of Yorkshire and Lancashire from each other.* Gritstone strata also form the Northern boundary of the district, and on the North-East of Blackburn, in North Lancashire, steeply inclined beds of coal, termed "rearing mines," are found,

* See the accompanying Map of the Coal District of South Lancashire.




COAL DISTRICT

OF

SOUTH LANCASHIRE

*Illustrated by*

*James Heywood F.G.S.*

1838.


NORTH
RED MARL
GRITSTONE
COAL
MEASURES
HILLS
LANCASHIRE
RED SANDSTONE
SOUTH LANCASHIRE
COAL MEASURES
CHESHIRE
RIVER MERSEY
LIVERPOOL
CHORLEY
BOLTON
BURY
ROCHDALE
MANCHESTER
WARRINGTON
BLACKBURN
PRESTON
WIGAN
Whitefield
Middleton
Edgworth
Over Darwen
Rossendale
Bickerstaffe
Ormskirk
Huyton
Prescot
Garston
Bootle
Great Crosby
Knowsley
Mawdesley
Leyland
Standish
Horwich
Haigh
Chowbent
Worsley
Stockport
Levels of Coal
Faults or Displacements
Scale of Miles
COAL DISTRICT
OF
SOUTH LANCASHIRE
Illustrated by
James Heywood F.G.S.
1848

overlying the gritstone rocks of the Northern boundary.

Red sandstone strata occur three miles to the South-West of Blackburn, at Feniscowles-bridge; and the red sandstone formation may be subsequently traced, with its associated rocks, on the Western and Southern limits of the Lancashire coal district.

A remarkable circumstance occasionally attends the junction of the red sandstone formation with the coal measures of South Lancashire. Long promontories of red sandstone are there found to divide, to a considerable depth, the strata of the coal measures; they sometimes narrow gradually towards a point, nearly in an acute angle, within the coal formation, and then spread out, in the opposite direction, beyond the limits of the carboniferous rocks.

Several of these promontories of red sandstone have been observed on the Southern boundary of the Lancashire coal district, in the neighbourhood of Eccleston, and Worsley, in South Lancashire, but the principal promontory of red sandstone which has yet been discovered,

stretches out, in a South-Easterly direction, along the valley of the river Irwell, for about seven miles, from Ringley to Manchester.

The Western side of this red sandstone promontory of the valley of the Irwell, is bounded by the rocks of the coal formation, which are supposed to be thrown down, below the red sandstone, by a fault of 1000 yards of downcast to the North-East: but the Eastern side of the promontory is little known, being generally concealed by the sand and gravel beds, which frequently overlie the sandstone rocks, on both sides of the valley of the Irwell.

Between Ringley and Clifton, the fault, on the Western side of the red rock promontory, is visible, as it crosses the bed of the river Irwell, and its direction is North-West by West in that locality.

South of Clifton, red sandstone may be traced on the bed of the river Irwell, near Kersal Moor, Castle Irwell, and under the bridges between Manchester and Salford. On the Eastern side of Manchester, coal is found at Bradford, and the red sandstone rock occurs again to the East of

the Bradford collieries: coal is afterwards found above Bank-bridge, on the river Medlock, in the same vicinity; and the carboniferous rocks are then continued without interruption, to the gritstone hills on the Eastern boundary of the district, beyond Ashton and Oldham.

At Ardwick, on the Eastern side of Manchester, and very near to the town, several beds of limestone are found,* interstratified with beds of carboniferous shale: the inclination of the Ardwick limestone is conformable to that of the carboniferous strata, and tends towards the South West.

Nine miles to the West of Manchester, at Bedford, near Leigh, strata of Magnesian limestone occur, which are not conformable to the carboniferous strata in that neighbourhood.

From observations made at Bedford, near Leigh, by the late Dr. Phillips, of Manchester, and communicated by that able inquirer to the author of this paper, it appears, that the strata of the Magnesian limestone at Bedford tend to the South-East, and

* All beds of limestone are coloured blue, in the accompanying Map of the Coal District.

that the red sandstone rocks of the same locality dip to the East, with a slight inclination towards the South, while the carboniferous gritstone, against which the Magnesian limestone there rests, dips rapidly to the South-West; hence the carboniferous grit rocks of Bedford are manifestly unconformable, both to the red sandstone, and to the Magnesian limestone of that portion of the South Lancashire coal district.

Several parallel faults occur in the coal district, on the Northern and North-Western side of Manchester, which have a North-Westerly direction, parallel to the great red rock fault of the valley of the Irwell, and which give an appearance of great regularity to the divisions of this portion of the coal district.

Two of these parallel faults were noticed by a scientific agent, surveying for the author, on the banks of the river Irwell, at Brandlesholme, North of Bury, in South Lancashire. The first of the two faults was observed to separate the strata of the dark ferruginous shale of that neighbourhood, from the carboniferous sandstone, and to change the inclination of the strata adjacent to it on both sides. Above the fault, the inclina-

tion of the dark ferruginous shale was 14° or 15° N.E. by E., and below the fault the inclination of the carboniferous sandstone was 5° South. Sandstone strata succeeded to the dark ferruginous shales, above the fault, with a similar inclination of 15° to 20° N.E. by E., and in these sandstones, the second fault occurred, in which the strata of sandstone were projected vertically upwards, and were accompanied by ferruginous septaria. In the line of the fault, ferruginous clay was found, filling up an interval of six feet in width, occasioned by the fault. The dip of the carboniferous sandstone strata above the second fault, was from 5° to 10° East.

On the opposite side of the river, the effects of the same faults were visible, from the vertical position of the sandstone strata, in the lines of the faults, contrasting with the uniformly gentle inclination of the carboniferous sandstones in that vicinity.

Similar phenomena accompanied the appearance of the same parallel faults on the river Roch, between Bury and Heywood. The general inclination of the carboniferous strata, on each side of the faults, was there very gentle, and did not exceed 10° to the South-East, while in the lines

of the faults, the beds of sandstone and the strata of black shale were forced vertically upwards.

Such an abrupt and singular change of the position of the strata probably occurred at a very remote period of time, when the beds were still soft and flexible, and when the strata might have been forced into a vertical position in the lines of the faults, without materially affecting the inclination of the adjacent portions of the coal formation.

Numerous alterations in the position of the beds of coal, have been, in ancient times, produced by the occurrence of faults; thus, in the higher rocks of the carboniferous series, between Worsley and the river Irwell, near Manchester, the level of the four feet coal mine has been repeatedly changed. At Roe Green, near Worsley, this mine has been removed towards the North, by a fault of 400 yards. Between Roe Green and Clifton, the direction of the level of the mine has been altered, by a fault of 600 yards, to a South-Easterly direction, tending towards the great red rock fault of the valley of the Irwell; and on the Eastern side of the great Irwell fault, the level of the four feet mine has been again removed, so that it is found to be

parallel to the direction of the fault, near Ringley.

In addition to the changes of position of the carboniferous rocks, in consequence of faults, the thickness and the structure of the various strata are liable to constant modifications, in different localities, in South Lancashire.

Some of the beds occasionally thin out, or they increase in thickness; others vary in their mineral structure, and are only identified with each other, by the strata which are associated with them.

Specimens of the mineral structure of the South Lancashire coal district, are presented in the following sections, which have been collected in different parts of the coal field, by various individuals, who have contributed them in a most friendly manner, while they have at the same time materially assisted the author of this paper in the illustration of those portions of the district with which they were, from local experience, intimately acquainted.

Nearly all the towns of South Lancashire are indebted for a large amount of their manufac-

turing power, to the economical supply of fossil fuel from neighbouring coal mines; and the carboniferous series of this district contains many other strata, in addition to the beds of coal, which are of considerable interest to the geologist.

VERTICAL SECTION OF STRATA, IN THE LOWER PART OF THE CARBONIFEROUS SERIES, AT THE LOWER CARR PIT, NEAR WIGAN, FROM MR. ALEXANDER HALIBURTON.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Soil and marl | 5 | 0 | 0 |
| Black bass | 1 | 0 | 0 |
| White rock | 1 | 1 | 9 |
| White earth | 0 | 1 | 6 |
| White earth | 0 | 1 | 6 |
| Soft blue stone (termed lin and wool) | 6 | 2 | 4 |
| White earth | 1 | 0 | 5 |
| Soft blue stone | 0 | 1 | 0 |
| Blue mine | 0 | 1 | 3 |
| Black bass | 0 | 1 | 3 |
| *Yard coal mine* | 1 | 0 | 1 |
| Warren, or black shaly earth | 0 | 2 | 0 |
| Soft blue stone | 1 | 1 | 6 |
| White rock | 3 | 1 | 2 |
| White earth | 1 | 2 | 0 |
| Soft blue stone | 2 | 0 | 0 |
| White earth | 0 | 2 | 5 |
| Hard rock | 0 | 2 | 0 |
| White earth | 0 | 1 | 0 |
| Rock | 0 | 2 | 2 |
| White earth | 1 | 0 | 6 |
| Carried forward | 31 | 1 | 10 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 31 | 1 | 10 |
| Rock | 1 | 0 | 3 |
| Soft blue stone | 4 | 2 | 5 |
| Hard rock | 1 | 2 | 6 |
| Soft blue stone and ironstone | 5 | 0 | 6 |
| White earth | 3 | 1 | 11 |
| Black bass | 3 | 2 | 8 |
| Rock | 2 | 2 | 9 |
| Rock | 3 | 0 | 3 |
| White rock | 3 | 0 | 1 |
| Rock | 0 | 2 | 3 |
| Dark soft blue stone | 4 | 0 | 9 |
| Bass | 0 | 2 | 6 |
| *Bone coal* | 0 | 2 | 3 |
| Soft blue stone | 1 | 0 | 2 |
| Rock | 1 | 0 | 0 |
| Soft blue stone | 0 | 2 | 4 |
| Rock | 0 | 1 | 2 |
| Soft blue stone | 0 | 2 | 5 |
| Ironstone | 0 | 0 | 5 |
| Soft blue stone | 1 | 0 | 0 |
| Strong white earth | 4 | 0 | 0 |
| Soft blue stone | 0 | 2 | 7 |
| Band | 0 | 1 | 1 |
| White earth | 0 | 1 | 0 |
| Interval | 0 | 1 | 1 |
| Soft blue stone | 3 | 1 | 5 |
| White earth with ironstone | 5 | 1 | 8 |
| Bass | 0 | 1 | 6 |
| White earth | 0 | 1 | 2 |
| *Coal* | 0 | 1 | 2 |
| Carried forward | 89 | 0 | 1 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 89 | 0 | 1 |
| White earth and ironstone | 2 | 0 | 0 |
| *Coal* | 0 | 2 | 3 |
| White earth | 0 | 2 | 9 |
| Rock | 6 | 0 | 3 |
| White earth | 1 | 2 | 0 |
| Soft blue stone | 1 | 1 | 6 |
| White earth | 1 | 1 | 8 |
| Soft blue stone | 0 | 1 | 2 |
| White earth | 0 | 1 | 10 |
| Bass | 0 | 2 | 4 |
| Soft blue stone | 1 | 1 | 5 |
| *Coal* | 0 | 0 | 9 |
| Soft blue stone | 3 | 0 | 3 |
| White earth | 2 | 1 | 0 |
| *Coal* and bass | 0 | 0 | 8 |
| White earth | 3 | 1 | 4 |
| Dark soft blue stone | 2 | 2 | 0 |
| Warren, or black shaly earth | 0 | 1 | 7 |
| Soft blue stone | 3 | 1 | 7 |
| Hard grit | 1 | 0 | 2 |
| Stiff blue stone | 4 | 2 | 11 |
| White earth and bands | 10 | 1 | 0 |
| Bass | 5 | 2 | 2 |
| White earth | 1 | 1 | 7 |
| Black bass | 3 | 1 | 3 |
| *Coal* | 2 | 0 | 0 |
| White earth | | | |
| White rock | 5 | 0 | 0 |
| Soft blue stone | 2 | 0 | 0 |
| White earth | 2 | 0 | 0 |
| Carried forward | 160 | 2 | 6 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 160 | 2 | 6 |
| *Coal* | 0 | 0 | 9 |
| Warren, or black shaly earth | | | |
| White rock | 1 | 0 | 0 |
| Soft blue stone, or lin and wool | 2 | 0 | 0 |
| Depth of Section ... Yards | 164 | 0 | 3 |

VERTICAL SECTION OF BEDS OF COAL, AT HAIGH, NEAR WIGAN, FROM MR. ALEXANDER HALIBURTON.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Depth from surface | 10 | 0 | 0 |
| Coal, which burns to a white ash | 1 | 0 | 6 |
| Interval | 8 | 0 | 0 |
| Confluent coal, of good quality | 0 | 2 | 6 |
| Interval | 16 | 0 | 0 |
| Coal, of sulphureous and shaly nature | 0 | 2 | 6 |
| Interval | 24 | 0 | 0 |
| Good coal, but not confluent | 1 | 1 | 0 |
| Interval | 32 | 0 | 0 |
| Coal, part confluent, and part not confluent | 2 | 1 | 0 |
| Interval | 12 | 0 | 0 |
| Good Furnace coal | 0 | 0 | 9 |
| Interval | 16 | 0 | 0 |
| Coal, in four beds, with strata of white earth between the beds | 3 | 0 | 0 |
| Interval | 120 | 0 | 0 |
| Cannel coal, which in other parts of the Lancashire coal basin is the upper stratum of coal, and has hitherto only been worked when it is the upper stratum | 1 | 0 | 0 |
| Carried forward | 248 | 2 | 3 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 248 | 2 | 3 |
| Interval | 24 | 0 | 0 |
| Good confluent coal in three beds | 1 | 2 | 0 |
| Interval | 32 | 0 | 0 |
| Coal in three beds of bad quality | 1 | 2 | 6 |
| Interval | 40 | 0 | 0 |
| Excellent furnace coal | 1 | 0 | 0 |
| Interval | 48 | 0 | 0 |
| Good furnace coal | 0 | 2 | 3 |
| Interval | 1 | 2 | 3 |
| Stratum of Cannel, intimately blended with Unio shells, about | 0 | 0 | 9 |
| Interval | 22 | 0 | 0 |
| Coal in three beds | 1 | 2 | 0 |
| Interval | 64 | 0 | 0 |
| Lowest coal of a confluent nature, and the best for domestic use | 2 | 0 | 0 |
| Total depth of Section ........Yards | 489 | 2 | 0 |

VERTICAL SECTION OF STRATA, IN THE LOWER PART OF THE CARBONIFEROUS SERIES, AT WIGAN, FROM MR. WILLIAM PEACE.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Soil, sand, gravel and loam | 12 | 1 | 6 |
| *Coal* | 0 | 0 | 9 |
| Warren earth | 0 | 1 | 8 |
| Tender light blue metal, dark towards the bottom | 4 | 2 | 6 |
| Bluish metal, with ironstone bands | 34 | 2 | 9 |
| Grey flaggy stone (perishes with the atmosphere) | 1 | 0 | 2 |
| Blue metal with ironstone bands | 8 | 0 | 6 |
| Carried forward | 62 | 0 | 10 |

| | | | Yds. | Ft. | In. |
|---|---|---|---|---|---|
| Brought forward | | | 62 | 0 | 10 |
| White rock | | | 25 | 0 | 0 |
| Blue metal | | | 1 | 0 | 2 |
| Black bass | | | 0 | 0 | 10 |
| *Coal* | 1F. | 4I. | | | |
| Blue Metal | 0 | 3 | | | |
| *Coal* | 3 | 6 | 1 | 2 | 10 |
| Strong black metal | 0 | 1 | | | |
| *Coal* | 0 | 8 | | | |
| Warren earth | | | 2 | 0 | 8 |
| Bass and dirt | | | 1 | 0 | 0 |
| White metal | | | 5 | 0 | 9 |
| White rock, very free, cuts well | | | 12 | 2 | 0 |
| Grey linsey | | | 1 | 0 | 0 |
| Blue metal | | | 2 | 0 | 4 |
| Coal mixed with leys of bass | | | 2 | 1 | 7 |
| Interval about | | | 44 | 0 | 0 |
| Soil and clay | | | 1 | 1 | 0 |
| Shaly rock | | | 1 | 0 | 0 |
| Dark shale | | | 0 | 2 | 0 |
| White rock | | | 1 | 2 | 10 |
| Dark shale | | | 1 | 0 | 8 |
| White rock | | | 1 | 2 | 6 |
| Dark shale | | | 0 | 1 | 0 |
| White rock | | | 0 | 1 | 10 |
| Dark shale | | | 0 | 2 | 2 |
| White rock | | | 0 | 1 | 3 |
| Dark shale | | | 0 | 0 | 11 |
| White rock | | | 2 | 0 | 1 |
| Dark shale | | | 0 | 2 | 2 |
| Carried forward | | | 174 | 1 | 5 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 174 | 1 | 5 |
| White rock | 1 | 2 | 5 |
| Metal | 2 | 0 | 0 |
| Black bass | 0 | 2 | 3 |
| Lin and wool | 4 | 2 | 3 |
| *Coal* | 0 | 0 | 3 |
| Warren earth | 0 | 0 | 6 |
| Lin and wool | 5 | 0 | 6 |
| White rock | 0 | 1 | 10 |
| Lin and wool | 2 | 2 | 6 |
| White stone | 1 | 0 | 0 |
| Metal | 0 | 0 | 6 |
| White stone | 0 | 2 | 3 |
| Lin and wool | 1 | 0 | 3 |
| White stone | 0 | 2 | 0 |
| Lin and wool | 1 | 0 | 9 |
| White stone | 1 | 0 | 6 |
| Lin and wool | 3 | 0 | 7 |
| Black bass | 0 | 1 | 11 |
| Dun metal | 3 | 1 | 1 |
| *Coal* | 0 | 0 | 3 |
| Dun bass and metal | 1 | 2 | 8 |
| Black and dun bass | 2 | 0 | 10 |
| Dun bass and metal | 0 | 2 | 10 |
| *Good coal* | 0 | 0 | 10 |
| Coal and bass | 0 | 2 | 4 |
| White stone | 0 | 2 | 0 |
| Lin and wool | 1 | 1 | 2 |
| White stone | 0 | 2 | 6 |
| White metal | 0 | 2 | 7 |
| Carried forward | 205 | 5 | 9 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 215 | 2 | 9 |
| Metal | 1 | 1 | 8 |
| Black bass | 0 | 2 | 5 |
| Brown stone | 0 | 0 | 4 |
| Bastard cannel | 0 | 0 | 11 |
| *Good cannel* | 0 | 2 | 8 |
| Dark brown stone | 3 | 1 | 11 |
| Dun metal | 2 | 0 | 3 |
| *Top coal* | 0 | 1 | 6 |
| Dark metal | 0 | 1 | 4 |
| *Bottom coal* | 0 | 1 | 5½ |
| Bass and metal | 0 | 1 | 0 |
| Warren earth | 0 | 0 | 7 |
| *Queen coal* | 0 | 1 | 3 |
| Black metal | 0 | 1 | 0 |
| Warren earth | 1 | 2 | 3 |
| Gray metal | 2 | 2 | 7 |
| Lin and wool | 1 | 1 | 10 |
| Blue bur | 1 | 1 | 2 |
| Gray metal | 8 | 1 | 9 |
| *Coal* | 0 | 1 | 2 |
| Warren earth | 0 | 2 | 7 |
| Lin and Wool | 1 | 0 | 10 |
| Loggy metal | 3 | 0 | 8 |
| *Ravine coal* | 0 | 1 | 10 |
| Metal | 0 | 1 | 2 |
| *Ravine coal* | 0 | 1 | 3 |
| Warren earth | 1 | 2 | 3 |
| Dark lin and wool | 6 | 2 | 9 |
| Carried forward | 260 | 0 | 1½ |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 260 | 0 | 1½ |
| Brown bur | 0 | 1 | 5 |
| Loggy metal | 11 | 0 | 8 |
| Black bass and coal | 0 | 2 | 0 |
| Warren earth | 1 | 0 | 3 |
| Lin and wool | 2 | 0 | 10 |
| *Cannel and coal* | 0 | 2 | 0 |
| Warren earth | 0 | 2 | 0 |
| Dark metal | 4 | 1 | 2 |
| Stone | 1 | 0 | 8 |
| Lin and wool | 0 | 1 | 8 |
| White rock | 10 | 1 | 11 |
| Gray metal | 2 | 1 | 8 |
| *Cannel* | 0 | 0 | 5 |
| Black metal | 2 | 2 | 2 |
| Stone | 0 | 1 | 4 |
| Lin and wool | 1 | 0 | 0 |
| Gray metal | 9 | 1 | 9 |
| Earth | 1 | 0 | 0 |
| Metal | 2 | 0 | 0 |
| Rock | 0 | 2 | 0 |
| Metal | 3 | 0 | 0 |
| *Coal* | 0 | 0 | 4 |
| Earth | 1 | 1 | 0 |
| Stone | 2 | 0 | 0 |
| Strong lin and wool | 3 | 0 | 0 |
| Stone | 25 | 0 | 0 |
| Bass (shale) | 1 | 1 | 0 |
| Warren earth | 1 | 0 | 0 |
| Carried forward | 350 | 2 | 4½ |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 350 | 2 | 4½ |
| Lin and wool (stone) | 2 | 2 | 0 |
| Ditto | 3 | 0 | 0 |
| Metal | 3 | 0 | 0 |
| Bass | 1 | 0 | 0 |
| *Bone coal* | 0 | 2 | 4 |
| Warren | 0 | 1 | 0 |
| Rock | 1 | 2 | 0 |
| Lin and wool | 1 | 0 | 0 |
| Metal | 3 | 0 | 0 |
| *Coal* | 0 | 0 | 4 |
| Warren | 1 | 1 | 0 |
| Rock | 1 | 0 | 0 |
| Lin and wool | 1 | 1 | 0 |
| Hard brown stone | 1 | 0 | 0 |
| Strong lin and wool | 2 | 0 | 0 |
| Bur (galliard) | 1 | 1 | 0 |
| Strong lin and wool | 3 | 0 | 0 |
| Metal | 7 | 0 | 0 |
| *Coal* | 0 | 1 | 0 |
| Warren | 0 | 1 | 0 |
| *Coal* | 0 | 1 | 2 |
| Warren | 0 | 1 | 6 |
| *Smith Coal* | 0 | 2 | 2 |
| Warren | 1 | 0 | 0 |
| Rock | 3 | 0 | 0 |
| Lin and Wool | 2 | 0 | 0 |
| Metals | 6 | 0 | 0 |
| Bass | 1 | 0 | 0 |
| Carried forward | 400 | 1 | 10½ |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 400 | 1 | 10½ |
| Cockle shell bed | 0 | 2 | 6 |
| Dun bass | 2 | 0 | 0 |
| *Bastard cannel* | 0 | 0 | 6 |
| Warren | 1 | 0 | 0 |
| Rock | 2 | 0 | 0 |
| Strong lin and wool | 4 | 0 | 0 |
| Metals | 8 | 0 | 0 |
| Lin and wool | 2 | 0 | 0 |
| Metals | 8 | 0 | 0 |
| Dun bass | 4 | 0 | 0 |
| Metals | 5 | 0 | 0 |
| Bass | 6 | 0 | 0 |
| White earth | 2 | 0 | 0 |
| Bass | 2 | 1 | 0 |
| *Buzzard coal* | 0 | 1 | 0 |
| *Main coal* | 1 | 1 | 5 |
| Grey metal | 0 | 1 | 8 |
| Lin and wool | 9 | 1 | 4 |
| Coal and bass | 1 | 0 | 0 |
| Dark grey stone | 2 | 1 | 6 |
| Grit, white stone | 3 | 1 | 3 |
| Blue metal | 5 | 0 | 8 |
| Grit, white stone | 1 | 1 | 4 |
| Dark metal | 5 | 2 | 10 |
| Black bass | 6 | 2 | 6 |
| Grit, white stone | 11 | 1 | 8 |
| Dark metal | 2 | 0 | 8 |
| Lin and wool | 3 | 2 | 4 |
| Carried forward | 503 | 2 | 0½ |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 503 | 2 | 0½ |
| White stone | 5 | 0 | 11 |
| Light metal | 9 | 2 | 6 |
| Grit, white stone | 4 | 1 | 10 |
| Strong metal | 10 | 0 | 10 |
| Grit, white stone | 7 | 0 | 4 |
| Lin and wool | 9 | 1 | 2 |
| Grit, white stone | 2 | 0 | 0 |
| Strong metal with bands | 9 | 1 | 7 |
| Soft stone | 3 | 0 | 7 |
| Strong metal | 4 | 0 | 5 |
| Soapy metal | 3 | 2 | 1 |
| Lin and wool | 4 | 2 | 10 |
| Soapy metal | 4 | 2 | 10 |
| Soapy metal, with bands | 20 | 2 | 10 |
| Black bass, with iron bands | 17 | 2 | 10 |
| Soapy metal | 13 | 1 | 2 |
| Dark ditto | 4 | 2 | 8 |
| Blue metal with iron bands | 6 | 1 | 8 |
| Black bass | 9 | 1 | 9 |
| Coal and bass | 0 | 1 | 7 |
| Hard brown stone | 2 | 0 | 4 |
| Brown stone | 8 | 2 | 6 |
| Strong dun metal | 2 | 2 | 2 |
| Lin and wool | 3 | 0 | 8 |
| Ditto | 4 | 2 | 10 |
| Ditto | 10 | 0 | 0 |
| Black Bass | 9 | 0 | 11 |
| Dark dun metal | 5 | 2 | 5 |
| Carried forward | 703 | 1 | 3½ |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 703 | 1 | 3½ |
| Black bass | 1 | 1 | 2 |
| Grit, white stone | 1 | 0 | 0 |
| Blue metal | 0 | 0 | 4 |
| Unproved interval probably about | 10 | 0 | 0 |
| White rock | 4 | 0 | 2 |
| Brown bur | 0 | 1 | 4 |
| Grey rock | 7 | 2 | 2 |
| Soft ditting | 0 | 0 | 3 |
| White rock | 1 | 1 | 0 |
| Lin and wool | 4 | 1 | 2 |
| White rock | 1 | 2 | 1 |
| Brown bur | 0 | 1 | 8 |
| Soft floor | 0 | 0 | 2 |
| White rock | 0 | 2 | 8 |
| Brown rock | 3 | 1 | 5 |
| Brown rock (very strong) | 1 | 1 | 2 |
| Brown bur | 0 | 1 | 6 |
| Shaly flag | 0 | 1 | 0 |
| Bur | 0 | 0 | 11 |
| White rock | 3 | 2 | 9 |
| Black stone | 1 | 0 | 1 |
| Black bass | 9 | 2 | 8 |
| Blue metal | 0 | 1 | 0 |
| Black bass | 4 | 1 | 10 |
| *Coal* | 0 | 1 | 5 |
| Warren | 2 | 0 | 6 |
| Black bass | 3 | 2 | 9 |
| *Coal* | 0 | 2 | 0½ |
| Carried forward | 770 | 0 | 6 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 770 | 0 | 6 |
| Dark warren | 1 | 1 | 4 |
| Strong lin and wool | 3 | 0 | 3 |
| Grey rock | 1 | 2 | 9 |
| Strong lin and wool | 1 | 0 | 4 |
| Grey rock | 1 | 1 | 6 |
| Lin and wool | 1 | 0 | 8 |
| Grey rock | 1 | 1 | 6 |
| Dark blue shale | 7 | 2 | 11 |
| Dark blue metal | 2 | 1 | 3 |
| Black bass | 1 | 0 | 10 |
| Dark warren | 0 | 1 | 2 |
| *Coal* | 0 | 0 | 4 |
| Light warren | 0 | 0 | 6 |
| Hard brown rock | 0 | 0 | 10 |
| Dun warren | 0 | 2 | 0 |
| Red shale | 1 | 1 | 8 |
| Hard gritty rock | 6 | 1 | 0 |
| Hard red bur | 1 | 0 | 7 |
| Red gritty stone | 2 | 0 | 6 |
| Dark blue stone | 1 | 1 | 9 |
| Dark dun metal | 5 | 0 | 9 |
| Black bass | 4 | 2 | 10 |
| Dark dun metal | 0 | 1 | 6 |
| Cement stone | 0 | 0 | 4 |
| Dark warren | 0 | 0 | 8 |
| Dark lin and wool | 0 | 2 | 1 |
| Grey rock | 2 | 0 | 8 |
| Hard white rock | 0 | 1 | 4 |
| Carried forward | 822 | 1 | 4 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 822 | 1 | 4 |
| Dark blue metal | 4 | 1 | 11 |
| Strong lin and wool | 1 | 1 | 11 |
| Dark blue metal | 4 | 2 | 7 |
| Dark lin and wool | 4 | 1 | 2 |
| Lin and wool | 6 | 0 | 0 |
| Dark dun metal | 5 | 2 | 4 |
| Dark grey rock | 0 | 1 | 2 |
| White earth | 2 | 0 | 11 |
| Light red shale | 1 | 0 | 2 |
| Light blue metal | 1 | 1 | 4 |
| Dark dun metal | 9 | 2 | 3 |
| *Coal* | 0 | 1 | 4 |
| Bind | 0 | 0 | 6 |
| Strong dark metal | 0 | 1 | 0 |
| Strong lin and wool | 2 | 0 | 3 |
| Dark dun metal | 2 | 0 | 0 |
| Ditto with rock bands | 5 | 0 | 4 |
| Lin and wool | 1 | 0 | 7 |
| Dark dun metal | 2 | 2 | 6 |
| Lin and wool | 1 | 0 | 4 |
| Dark dun metal | 0 | 2 | 10 |
| Light blue metal | 1 | 1 | 4 |
| Dark dun metal | 1 | 0 | 0 |
| Dark dun shale | 1 | 1 | 9 |
| Hard white rock | 2 | 0 | 10 |
| Bur | 1 | 0 | 1 |
| Hard white rock | 1 | 0 | 5 |
| Total number of yards | 889 | 1 | 2 |

GENERAL VERTICAL SECTION OF THE BEDS OF COAL, AT HAIGH, NEAR WIGAN, FROM MR. PEACE.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Depth from surface | 62 | 0 | 0 |
| Top mine, (divided into two seams by 8 inches of fire clay) | 0 | 2 | 8 |
| Interval of other strata | 18 | 0 | 0 |
| Inferior coal | 0 | 1 | 3 |
| Interval | 30 | 0 | 0 |
| Little Delph mine | 0 | 2 | 6 |
| Interval | 16 | 0 | 0 |
| Yard coal | 1 | 0 | 0 |
| Interval | 10 | 0 | 0 |
| Inferior coal | 0 | 2 | 0 |
| Interval | 30 | 0 | 0 |
| Four feet coal | 1 | 1 | 0 |
| Interval | 30 | 0 | 0 |
| Seven feet coal | 2 | 1 | 0 |
| Interval | 16 | 0 | 0 |
| Coal | 2 | 2 | 0 |
| Interval | 1 | 0 | 0 |
| Fire clay | 0 | 2 | 6 |
| Interval | 16 | 0 | 0 |
| Coal | 0 | 1 | 6 |
| Warren earth | 0 | 1 | 0 |
| Interval | 1 | 0 | 0 |
| Coal | 0 | 1 | 3 |
| Interval | 80 | 0 | 0 |
| Wigan mine | 1 | 2 | 0 |
| Interval | 22 | 0 | 0 |
| Carried forward | 345 | 2 | 8 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 345 | 2 | 8 |
| Coal | 1 | 1 | 0 |
| Interval | 16 | 0 | 0 |
| Metal and coal, 9 feet mine | 3 | 0 | 0 |
| Interval | 94 | 0 | 0 |
| Cannel coal | 0 | 2 | 9 |
| King coal | 0 | 2 | 0 |
| Warren | 0 | 1 | 6 |
| Coal | 0 | 1 | 6 |
| Warren | 0 | 1 | 4 |
| Queen Coal | 0 | 1 | 0 |
| Interval | 38 | 0 | 0 |
| Ravine coal | 1 | 0 | 0 |
| Interval | 48 | 0 | 0 |
| Yard coal | 1 | 0 | 0 |
| Interval | 48 | 0 | 0 |
| Bone coal | 0 | 2 | 3 |
| Interval | 26 | 0 | 0 |
| Smith coal | 0 | 1 | 6 |
| Metal | 0 | 2 | 6 |
| Coal | 0 | 2 | 0 |
| Interval | 67 | 0 | 0 |
| Arley mine | 2 | 0 | 0 |
| Interval | 12 | 0 | 0 |
| Coal | 0 | 1 | 0 |
| Interval | 251 | 0 | 0 |
| Chorley mine | 1 | 0 | 0 |
| Interval | 100 | 0 | 0 |
| Mountain mine | 0 | 1 | 3 |
| Total depth of Section ......Yards | 1062 | 0 | 3 |

VERTICAL SECTION OF THE BEDS OF COAL, AT WHISTON, ON THE EASTERN SIDE OF LIVERPOOL, AND SOUTH-WEST OF WIGAN.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Felcroft mine | 2 | 1 | 0 |
| Interval of other strata | 32 | 0 | 0 |
| Pastures mine | 3 | 0 | 0 |
| Interval | 10 | 0 | 0 |
| Earthy delph | 2 | 0 | 0 |
| Interval | 12 | 0 | 0 |
| Yard mine | 1 | 0 | 2 |
| Interval | 12 | 0 | 0 |
| Cannel mine | 1 | 2 | 8 |
| Interval | 28 | 0 | 0 |
| Higher Bugs mine | 2 | 1 | 0 |
| Interval | 2 | 0 | 0 |
| Lower Bugs mine | 1 | 1 | 0 |
| Interval | 24 | 0 | 0 |
| Cheshire mine | 0 | 2 | 6 |
| Interval | 60 | 0 | 0 |
| Firlands | 3 | 2 | 0 |
| Interval | 20 | 0 | 0 |
| St. Sebastian's | 1 | 0 | 0 |
| Interval | 40 | 0 | 0 |
| Little Delph mine | 0 | 2 | 0 |
| Interval | 20 | 0 | 0 |
| Sir John mine | 1 | 0 | 6 |
| Interval | 40 | 0 | 0 |
| Main Delph | 4 | 0 | 0 |
| Interval | 80 | 0 | 0 |
| Rushy Park mine | 1 | 1 | 8 |
| Carried forward | 406 | 2 | 6 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 406 | 2 | 6 |
| Interval | 50 | 0 | 0 |
| Yew Tree mine | 1 | 0 | 0 |
| Total depth of Section ........Yards | 457 | 2 | 6 |

VERTICAL SECTION OF BEDS OF COAL, UNDER SMITHY BROW, IN PENDLEBURY, FOUR MILES TO THE NORTH-WEST OF MANCHESTER, FROM MR. KNOWLES.

| | | | | Yds. | Ft. | In. |
|---|---|---|---|---|---|---|
| Depth from surface | | | | 40 | 0 | 0 |
| Fitzgerald's yard mine | | | | 0 | 2 | 6 |
| Interval of other strata | | | | 85 | 0 | 0 |
| Four feet mine | | | | 1 | 1 | 0 |
| Interval | | | | 6 | 0 | 0 |
| Pendlebury mine | | | | 0 | 1 | 6 |
| Interval | | | | 40 | 0 | 0 |
| Pendlebury mine | 0 | 2 | 0 | | | |
| | 0 | 1 | 6 | | | |
| | 0 | 2 | 3 — | 1 | 2 | 9 |
| Interval | | | | 220 | 0 | 0 |
| Bin mine | | | | 1 | 0 | 0 |
| Interval | | | | 80 | 0 | 0 |
| Crombuck mine | | | | 1 | 0 | 0 |
| Interval | | | | 37 | 0 | 0 |
| Brassey mine | | | | 1 | 0 | 0 |
| Interval | | | | 11 | 0 | 0 |
| Ram's mine | | | | 2 | 1 | 0 |
| Interval | | | | 29 | 0 | 0 |
| Dye-house mine | | | | 0 | 1 | 6 |
| Carried forward | | | | 558 | 1 | 3 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 558 | 1 | 3 |
| Interval | 22 | 0 | 0 |
| Coal mine | 0 | 2 | 0 |
| Interval | 8 | 0 | 0 |
| Black and White mine | 2 | 0 | 0 |
| Interval | 50 | 0 | 0 |
| Doe mine | 2 | 1 | 6 |
| Interval | 80 | 0 | 0 |
| Five quarters' mine | 0 | 3 | 9 |
| Interval | 11 | 0 | 0 |
| Hell-hole mine | 0 | 2 | 0 |
| Interval | 36 | 0 | 0 |
| Trencher-bone mine | 1 | 1 | 0 |
| Interval | 70 | 0 | 0 |
| Dixon Green mine | 0 | 2 | 0 |
| Interval | 13 | 0 | 0 |
| Cannel Coal | 1 | 0 | 6 |
| Interval | 66 | 0 | 0 |
| Plodder mine | 1 | 1 | 0 |
| Interval | 53 | 0 | 0 |
| Yard mine | 0 | 2 | 0 |
| Interval | 40 | 0 | 0 |
| Half yard mine | 0 | 1 | 6 |
| Interval | 46 | 0 | 0 |
| Three quarters' mine | 0 | 2 | 0 |
| Interval | 18 | 0 | 0 |
| Daubhill mine | 1 | 1 | 0 |
| Interval | 75 | 0 | 0 |
| Total depth of Section ......Yards | 1161 | 0 | 6 |

SECTION OF THE CARBONIFEROUS STRATA, AT THE DEAN GATE COAL PIT, NEAR BOLTON, FROM MR. AINSWORTH, M.P.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Marl | 16 | 0 | 0 |
| Black shale | 13 | 0 | 0 |
| Light rag | 3 | 0 | 0 |
| Black shale | 2 | 0 | 0 |
| Black bass | 2 | 0 | 0 |
| Soapstone | 0 | 1 | 6 |
| Black bass | 2 | 0 | 0 |
| Coal | 0 | 0 | 10 |
| Hard bur rock | 0 | 1 | 0 |
| Warren earth | 0 | 2 | 6 |
| White rock | 1 | 2 | 0 |
| White earth | 1 | 0 | 0 |
| Bright rag | 0 | 1 | 7 |
| Coal | 0 | 2 | 0 |
| Total depth of Section ....Yards | 43 | 2 | 5 |

SECTION OF THE CARBONIFEROUS STRATA, AT GLODWICK, NEAR OLDHAM, FROM MR. F. LOONEY, F.G.S.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Red clay | 1 | 1 | 6 |
| Marl | 2 | 1 | 6 |
| Red rock | 15 | 0 | 0 |
| White rock | 1 | 2 | 0 |
| Neeld mine coal | 0 | 0 | 10 |
| White rock | 0 | 1 | 0 |
| Floor dirt | 0 | 2 | 2 |
| Soapstone | 0 | 2 | 0 |
| White rock | 5 | 1 | 6 |
| Soapstone | 1 | 1 | 3 |
| Carried forward | 29 | 1 | 9 |

| | | Yds. | Ft. | In. |
|---|---|---|---|---|
| Brought forward | | 29 | 1 | 9 |
| Coal | | 0 | 0 | 6 |
| Soapstone | | 0 | 2 | 0 |
| White rock | | 1 | 2 | 0 |
| Mixture of rock and soapstone | | 1 | 0 | 0 |
| Soapstone and ironstone | | 0 | 0 | 6 |
| White rock | | 1 | 0 | 5 |
| Soapstone | | 2 | 0 | 0 |
| Pomfret mine | Tops | 0 | 2 | 0 |
| | Stone | 0 | 0 | 7 |
| | Middle coal | 0 | 0 | 11 |
| | Blackstone and dirt | 0 | 0 | 10 |
| | Bottom coal | 0 | 1 | 0 |
| Floor dirt | | 0 | 1 | 2 |
| Soapstone | | 0 | 0 | 2 |
| White rock | | 0 | 1 | 2 |
| Soapstone | | 13 | 0 | 0 |
| Blue soapstone | | 2 | 0 | 0 |
| White rock | | 1 | 0 | 0 |
| Blue rock | | 2 | 0 | 0 |
| Blendfire rock (not sunk through) | | 42 | 0 | 0 |
| Rock (not a building stone) | | 14 | 1 | 6 |
| Shale | | 4 | 0 | 0 |
| Soapstone | | 5 | 1 | 6 |
| Little coal | | 0 | 0 | 6 |
| Soapstone | | 1 | 1 | 0 |
| Great mine | Black coal | 0 | 1 | 10 |
| | Bastard coal | 0 | 0 | 6 |
| | Bright coal | 0 | 0 | 10 |
| | Soapstone | 0 | 1 | 0 |
| | Carried forward | 125 | 2 | 8 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 125 | 2 | 8 |
| Stone coal | 0 | 0 | 10 |
| Dirt | 0 | 0 | 5 |
| Hard ones | 0 | 1 | 10 |
| Parting | 0 | 0 | 2 |
| Great mine coal | 1 | 1 | 6 |
| Soapstone | 11 | 0 | 0 |
| Little mine | 0 | 2 | 3 |
| Soapstone, with ironstone beds | 21 | 0 | 0 |
| Total depth of Section ......Yards | 161 | 0 | 8 |

SECTION OF STRATA, AT THE BYE PIT, IN DUKINFIELD, NEAR ASHTON, FROM MR. F. LOONEY, F.G.S.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Raised on the top of the coal pit | 4 | 0 | 0 |
| Soil and clay | 1 | 0 | 4 |
| Sand | 5 | 1 | 8 |
| Marl | 1 | 1 | 9 |
| Coal | 0 | 2 | 3 |
| Fire clay | 1 | 1 | 10 |
| White metal | 13 | 0 | 0 |
| Dark metal | 10 | 0 | 4 |
| Fire clay | 4 | 2 | 0 |
| Coal | 0 | 0 | 10 |
| Fire clay | 1 | 1 | 9 |
| Dark marl | 13 | 2 | 3 |
| Rock bands | 0 | 0 | 10 |
| Dark metal | 0 | 1 | 3 |
| Dark rock band | 1 | 1 | 9 |
| Carried forward | 60 | 0 | 10 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 60 | 0 | 10 |
| Strong white metal | 7 | 2 | 10 |
| Black shale | 0 | 0 | 3 |
| Black stone | 0 | 0 | 9 |
| Swire's mine | 0 | 1 | 8 |
| Black shale | 1 | 2 | 6 |
| Fire clay | 2 | 2 | 0 |
| Dark warren earth or clay | 0 | 1 | 6 |
| Strong dark metal | 5 | 2 | 3 |
| Black bath | 0 | 1 | 0 |
| Coal | 0 | 1 | 0 |
| Fire Clay | 1 | 2 | 0 |
| Grey metal | 19 | 1 | 5 |
| Soft soapstone | 0 | 1 | 1 |
| Black bath | 0 | 0 | 4 |
| Sod's coal mine | 0 | 2 | 8 |
| Sod or grey metal | 0 | 2 | 1 |
| Under coal, below Sod's mine | 0 | 3 | 6 |
| Soft fire clay | 0 | 1 | 11 |
| Grey band | 1 | 1 | 0 |
| Strong blue metal | 5 | 1 | 6 |
| Dirt and coal | 0 | 1 | 4 |
| Warren earth | 0 | 1 | 11 |
| Coal | 0 | 0 | 4 |
| Total depth of Section ......Yards | 113 | 1 | 8 |

SECTION OF STRATA, AT THE WELLINGTON PIT, NEAR ASHTON, FROM MR. THOMAS ASHTON, JUN.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Depth, from the surface to the park mine | 16 | 2 | 6 |
| Carried forward | 16 | 2 | 6 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 16 | 2 | 6 |
| Park mine | 0 | 2 | 1 |
| Metal to foxholes mine | 24 | 1 | 6 |
| Foxholes mine | 0 | 2 | 0 |
| Metal to cannel | 13 | 1 | 2 |
| Cannel | 0 | 0 | 8 |
| Bad coal | 0 | 0 | 8 |
| Metal | 8 | 1 | 6 |
| Bad coal and cannel | 0 | 1 | 6 |
| Metal | 7 | 1 | 0 |
| Bad coal | 0 | 0 | 9 |
| Metal | 11 | 0 | 3 |
| Bad coal | 0 | 0 | 4 |
| Metal | 0 | 2 | 6 |
| Rock | 1 | 0 | 0 |
| Metal | 6 | 1 | 8 |
| Rock | 2 | 1 | 0 |
| Rock bands | 0 | 2 | 0 |
| Metal | 6 | 1 | 10 |
| Rock | 0 | 0 | 6 |
| Metal | 0 | 0 | 2 |
| Rock | 0 | 0 | 6 |
| Metal | 6 | 2 | 0 |
| Black shale | 7 | 1 | 0 |
| Chamber coal mine | 0 | 2 | 2 |
| Parting | 0 | 0 | 4 |
| Coal | 0 | 0 | 4 |
| Metal | 9 | 2 | 2 |
| Black shale | 0 | 1 | 6 |
| Coal | 0 | 0 | 9 |
| Carried forward | 128 | 0 | 4 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 128 | 0 | 4 |
| Metal | 10 | 2 | 3 |
| Red stone | 16 | 0 | 6 |
| Rock | 15 | 0 | 0 |
| Mixture of metals | 0 | 1 | 6 |
| Rock | 2 | 1 | 6 |
| Mixture of metals | 0 | 1 | 6 |
| Mixture of rock and metals | 10 | 1 | 6 |
| Rock | 3 | 0 | 0 |
| Metal | 0 | 1 | 6 |
| Rock and metals | 3 | 0 | 0 |
| Rock | 0 | 1 | 6 |
| Metal | 2 | 2 | 0 |
| Black stone | 0 | 1 | 0 |
| Metals | 32 | 0 | 0 |
| Rock | 2 | 2 | 5 |
| Blendfire coal mine | 0 | 1 | 2 |
| Parting | 0 | 0 | 5 |
| Coal | 0 | 1 | 0 |
| Metal | 11 | 2 | 0 |
| Bad coal | 0 | 0 | 7 |
| Metal | 7 | 1 | 5 |
| Rock | 3 | 0 | 0 |
| Metal, top of the great mine | 4 | 2 | 7 |
| Great mine, first coal | 0 | 1 | 4 |
| Parting | 0 | 0 | 5 |
| Second coal | 0 | 0 | 8 |
| Parting | 0 | 0 | 8 |
| Third coal | 0 | 0 | 6 |
| Metal | 14 | 0 | 0 |
| Carried forward | 272 | 0 | 3 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 272 | 0 | 3 |
| Salt petre mine, (not worth getting) | 0 | 1 | 10 |
| Parting | 0 | 0 | 4 |
| Bad coal | 0 | 1 | 0 |
| Metal | 6 | 0 | 4 |
| Little mine | 0 | 1 | 3 |
| Metal | 11 | 0 | 0 |
| Rock | 3 | 0 | 0 |
| Metal | 7 | 1 | 0 |
| Rock bands | 0 | 1 | 0 |
| Bad coal, foot mine | 0 | 0 | 7 |
| Metal | 2 | 2 | 8 |
| Rock | 4 | 0 | 0 |
| Rock and metal | 4 | 0 | 0 |
| Metal | 2 | 2 | 8 |
| Black mine | 1 | 1 | 0 |
| Metal below the black mine | 3 | 0 | 0 |
| Depth of Section Yards | 319 | 1 | 11 |

SECTION OF STRATA, AT THE BAYLEY-FIELD COLLIERY, AT HYDE, IN CHESHIRE, NEAR ASHTON, FROM MR. THOMAS ASHTON, JUN.

N. B.—The Shaft of the Bayley-field Colliery is sunk down to the Peacock Mine, and the remainder of the section, below the Peacock Mine, is obtained from the vertical thickness of the strata, in a tunnel, driven on the rise of the mines.

| | Yds. | Ft. | In. |
|---|---|---|---|
| Depth from the surface to the black mine | 100 | 0 | 0 |
| Black mine | 1 | 1 | 0 |
| Soapstone | 5 | 0 | 0 |
| Carried forward | 106 | 1 | 0 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 106 | 1 | 0 |
| Flagstone | 7 | 0 | 0 |
| Strong white rock | 3 | 0 | 0 |
| Grey flagstone | 5 | 2 | 0 |
| White soapstone | 1 | 0 | 0 |
| Strong brown rock | 0 | 1 | 0 |
| Brown rock, and black shale, and bands of iron-stone | 5 | 2 | 0 |
| Sydean mine, (good coal) | 0 | 1 | 4 |
| Black soapstone | 1 | 0 | 0 |
| White soapstone | 0 | 1 | 0 |
| Stone mine, varying in thickness, sometimes one yard thick | 0 | 2 | 9 |
| Floor earth | 1 | 0 | 0 |
| Soapstone | 1 | 1 | 6 |
| Very strong soapstone | 2 | 1 | 0 |
| Cannel coal | 0 | 2 | 6 |
| Warren earth, full of iron bands | 3 | 1 | 0 |
| Strong rock bands | 7 | 2 | 0 |
| Very strong white rock | 9 | 0 | 0 |
| Rock bands | 3 | 1 | 0 |
| Soapstone and pebbles of ironstone | 3 | 1 | 6 |
| Black clunch | 1 | 0 | 0 |
| Peacock mine | 0 | 2 | 6 |
| Warren earth | 1 | 0 | 0 |
| Good coals | 0 | 1 | 0 |
| Dark soapstone | 4 | 0 | 0 |
| Water mine, (good coals) | 0 | 0 | 5 |
| Dirt | 0 | 0 | 6 |
| Good coals, belonging to the water mine | 0 | 1 | 10 |
| Carried forward | 171 | 3 | 10 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 171 | 3 | 10 |
| Floor, with chitters of coal | 0 | 2 | 2 |
| Soft white warren | 0 | 0 | 3 |
| Strong brown rock | 1 | 0 | 0 |
| Rock bands | 3 | 0 | 0 |
| Soapstone | 3 | 1 | 0 |
| Black clunch | 1 | 0 | 0 |
| Sam Naley's mine, (good coals) | 0 | 1 | 4 |
| Fire clay | 0 | 2 | 6 |
| Coal | 0 | 1 | 3 |
| Metal | 2 | 0 | 0 |
| Rock | 1 | 0 | 6 |
| Strong rock bands | 3 | 1 | 0 |
| Metal | 27 | 0 | 0 |
| Roof of clunch and metal | 1 | 0 | 0 |
| Seddon's mine, (good coal) | 0 | 2 | 6 |
| Strong warren | 0 | 1 | 1 |
| Light coloured rock | 0 | 1 | 9 |
| Rock bur | 0 | 2 | 0 |
| Rock | 0 | 2 | 7 |
| Rock bur | 0 | 1 | 0 |
| Rock | 1 | 1 | 6 |
| Rock binds | 3 | 1 | 6 |
| Strong metal | 2 | 2 | 8 |
| Very black shale | 1 | 2 | 10 |
| Black shale | 0 | 1 | 6 |
| Very strong dark metal, with iron bands | 1 | 1 | 6 |
| Rock binds | 1 | 1 | 0 |
| Black shale | 1 | 0 | 3 |
| Soapstone | 1 | 1 | 0 |
| Carried forward | 236 | 2 | 6 |

| | Yds. | Ft. | In. |
|---|---|---|---|
| Brought forward | 236 | 2 | 6 |
| Strong metal.. | 1 | 1 | 1 |
| Soapstone | 2 | 0 | 4 |
| Flagstone binds | 1 | 0 | 4 |
| Very dark coloured strong rock binds | 2 | 0 | 10 |
| Black shale with chitters of coal | 0 | 1 | 9 |
| Roof of Lees mine, with chitters of coal | 2 | 0 | 0 |
| Lees coal mine | 0 | 2 | 8 |
| Floor, with chitters of coal | 0 | 2 | 6 |
| Very strong brown warren earth | 0 | 2 | 7 |
| Very strong rock binds | 6 | 0 | 0 |
| Black shale and soapstone | 1 | 0 | 9 |
| Rock binds | 1 | 0 | 3 |
| Very strong rock | 1 | 1 | 10 |
| Rock binds | 0 | 2 | 5 |
| Strong white rock | 0 | 2 | 9 |
| Rock binds | 1 | 0 | 0 |
| Rock bur | 1 | 0 | 3 |
| Very strong rock | 1 | 1 | 5 |
| Soapstone | 5 | 0 | 0 |
| White rock | 20 | 0 | 0 |
| New mine | 0 | 3 | 6 |
| Total depth of Section .....................Yards | 290 | 0 | 9 |

It may be observed that the two last sections are continuous, and that they include a series of strata, of more than 500 yards in depth, connected together by the occurrence of the black mine, (page 460); these sections display the order and succession of different varieties of strata, which owe their origin to the gradual formation of the coal measures, in periods of remote antiquity.

# OBSERVATIONS

ON

# SCULPTURE.

By PAUL MOON JAMES, Esq.

(Read the 7th January, 1840.)

The pleasure which we derive either from Music, from Architecture, or from Sculpture, is heightened or diminished by the possession or the absence of a cultivated taste; and the emotions of the mind will be more or less awakened into admiration or delight, according to our knowledge of the principles which ought to govern the labours of the artist, as well as the judgment of the Spectator.

What is the nature of those principles, and from what law or quality of our constitution they are derived, have been the subjects of frequent

enquiry, both by philosophers and by artists; and these have arrived at different conclusions respecting them. Some have resolved the emotion of Taste, directly into an original law of our nature; which supposes a sense or senses, by which the qualities of beauty and sublimity are perceived and felt as their appropriate objects; and conclude therefore that the genuine object of the Arts of Taste, is to discover and to imitate those qualities in every subject, which the prescription of nature has thus made, essentially, either beautiful or sublime.

To this class belong the theories of Hogarth, of the Abbe Winkleman, and perhaps the theory in its last result, of Sir Joshua Reynolds. It is the species of hypothesis, which is naturally resorted to by all artists and amateurs—by those whose habits of thought lead them to attend more to the causes of their emotions, than to the nature of the emotions themselves.

The second class of hypotheses arises from the opposite view of the subject. It is that which resists the idea of any new or peculiar sense, distinct from the common principles of our nature; which supposes some one known or acknowledged

principle, or affection of mind, to be the foundation of all the emotions we receive from the objects of taste; and which resolves therefore all the various phenomena, into some more general law of our intellectual or moral constitution. Of this kind are the hypothesis of M. Diderot, who attributes all the emotions of this kind to the perception of *relation:* of Mr. Hume, who resolves them into our sense of *utility:* of the venerable St. Austin, who, a thousand years ago, resolved them into the pleasure which belongs to the perception of *order* and *design.* It is the species of hypothesis most natural to retired and philosophic minds: to those whose habits have led them to attend more to the nature of the emotions they feel, than to the causes which produce them.

But I am not inclined to entangle myself in theories, which are plainly founded upon a *simplicity* of the *emotion* of *taste;* nor yet to analyze them, to shew that this *simplicity* is very little reconcileable with the most common experience of human feeling. I shall proceed at once to the consideration of the object or design in the mind of the Sculptor, and the principles of taste, which ought to govern us in our judgment of his works.

The most celebrated Statues, or specimens of sculpture, which have attracted the admiration of past and present generations, may be classed under three heads. 1.—The Imaginative. 2.—The Material. 3.—The two former blended.

The first class embraces the Heathen Divinities; the personifications of Virtues, Vices, Attributes, and Idealities.

The second, the imitations of the Human form, and the resemblance of Mortals.

The third includes the other two, and combines with the imitation of the outward form, expression of character, and indications of individual mental qualities.

The history of Sculpture amongst the Greeks, affords ample illustrations of the *imaginative* class. The intellectual and refined imaginations of the Athenians, led them to employ Phidias, to embody the conceptions of their vivid minds; and so sacred were the labours of the Sculptor amongst them, that these for a long period were confined to the representation of their deities; and the attempt to reduce the marble block to the likeness

of a mortal, was considered by the Athenians as a profanation of divinity, and a crime against the state.

Thus, in the statue of Minerva, which Phidias raised within the Parthenon, which was distinguished by its size, being nearly forty feet high: —for the richness of the materials, namely, gold and ivory:—and for the exquisite beauty of the workmanship, which was said to awaken the idea of sublime majesty. Phidias was reproached with having sculptured his own portrait, and that of his patron, Pericles, on the shield of Minerva. He had there represented himself as an old man, in the act of throwing a huge stone, whilst Pericles appeared fighting with an Amazon.

Another specimen of the "Imaginative" in Sculpture, was the statue and throne of Jupiter in Elis. This also was colossal, for the artist knew that vastness was an attribute of the sublime. It was sixty feet high,—was made of gold and ivory, as the most costly material for a divinity,—and the workmanship was most exquisite, so as to combine in the imagination of the beholders, the sentiment of beauty, as well as that of sublimity.

There was a little descent from the lofty imaginative, in the statue of Venus, by Praxiteles, at Cnidus. It is said to have been the model of perfect beauty; and the Ionians exclaimed that "Venus had forsaken Olympus and come down to dwell with them!" After all it was Venus under the form of Phryne; and it was further discovered that the statue had the enchanting smile of Cratine, another mistress of Praxiteles. I would therefore class this statue under the third head.

The Statuary of the Greeks is characterised by grace and beauty. That of the Romans by strength and dignity. Thus, in the busts and statues of the Roman Emperors, we are enabled, with the aid of medals, to appropriate to every Emperor his marble likeness; and to trace, in the expression of the features, those qualities which they displayed in their actions and which distinguish them in history. Some of these are unempassioned resemblances, whilst others represent action united with likeness, and these are called heroic.

The statues of Roman Women, are equally distinguished by the character we associate with

Roman Matrons. The figure in general, is unbending—the head erect—the expression severe—and full drapery envelopes the whole figure. Such is the statue which Benedict XIV. placed in the Museum of the Capitol, under the name of "Flora of the Capitol," and which is supposed to represent that Flora who was celebrated for her love of Pompey the Great.

The fine collection of Statuary which was brought to Paris, as part of the spoil of conquered nations, has been the means of increasing our knowledge of Greek and Roman Sculpture. After the peace of 1815, on the application of the British Government, that of France, with distinguished liberality, allowed casts to be taken and brought to England, thereby enriching it with the finest models, and consecutively improving the national taste.

I proceed now to make a few remarks on English Sculpture, which, considering the northern temperament of its Patrons, and the destructive qualities of our climate, has received considerable encouragement. Owing to the latter obstacle, specimens of art, in marble, are rarely exposed in the open air; and sombre casts in iron

or copper, bronzed, are substituted. Assisted by that delightful little volume, "The Lives of British Sculptors," by Allan Cunningham, I propose to notice, briefly, some of the works of English Sculpture, in chronological order, beginning with those of GRINLEY GIBBONS, who was patronized by Charles II., and James II., and who is well known by his exquisite carvings in wood, at Chatsworth and Petsworth.

He began with pedestals, and at Windsor wrought that fine pedestal in marble, on which the Equestrian Statue, by Stada, of Bremen, was placed; and afterwards the pedestal for the Charing Cross Statue, by the same hand. By its appropriate decorations, it has been said that the Windsor pedestal belongs to the line of Stuarts. That of Charing Cross would suit any statue of corresponding proportions. The statue of James, at Whitehall, was the work of Gibbons, who was employed by a certain Tobias Rustat, keeper of Hampton Court, and received five hundred pounds for it. It has great ease of attitude and a certain serenity of air, and is not unworthy of the hand that moulded it. Gibbons made a magnificent Tomb, for Baptist Noel, Viscount Cambden, in the Church of Exton, in Rutlandshire;

it cost a thousand pounds, is twenty-two feet high and fourteen wide.

Cibber, who had studied the heathen gods and goddesses at Rome, began a manufactory of Venuses and Dianas in London, and accommodating himself to the pockets of his customers, he wrought in a cheap material; and vindicated his choice by averring, that fine conception and skilful workmanship could consecrate *Freestone.* Our raw and inhospitable atmosphere, was soon found to wage a destructive war with this fragile race of divinities. We have the evidence of the Marbles of Minerva's Temple, in favour of the long endurance of Sculpture in the fine climate of Greece. But the rain, the haze, the hail, and the snow of our island, strips off the external beauty even of marble, in a few seasons, and with the outward grace, much that the many admire Sculpture for, has departed. So it fared with Cibber's labours in groves and gardens; and our Sculpture now no longer covets the open air, but seeks shelter in galleries, or takes sanctuary in the church. Nature says, that art can never be to Britain, what it was of old to Greece.

The most celebrated of Cibber's works are the

far famed figures of Madness and Melancholy, carved for the chief entrance to Moorfields. They are the earliest indications of a distinct and natural spirit in Sculpture, and stand first in conception, and only second in execution, among all the productions of the island.

The next Artist I shall notice is ROUBILIAC. His first work is supposed to be a statue of Handel, made for Vauxhall Gardens, which, after many removals and wanderings, was not long since purchased by Mr. Hamlet, the silversmith, for ten guineas. Every button of Handel's dress seems to have sat for its likeness, and every button-hole is finished with the fastidiousness of a fashionable tailor—whilst the clothes are infected with the agitation of the man, and are in staring disorder. They seem to be thrown on to meet the sudden exigency of some random fit of inspiration — his waistcoat is half unbuttoned—the knees of his breeches are loose—his hair is in motion, and he seems more like a man agitated by an apparition, than one influenced by the spirit of melody. It cannot fail to offend some tastes; but it will be a prime favourite with those—and how many are they!—who desire no more from

Sculpture than a fac-simile of the real man—
"Whose accuracy all men durst swear for."

But there is another statue by Roubiliac, which was made for Trinity College, Cambridge, and where it now stands, more worthy of the genius of the sculptor; and which will be preferred by all who love the serene dignity and graceful composure of the philosopher.—It is the statue of Sir Isaac Newton. Newton is represented standing, holding a prism; and between his hand and the thought stamped upon his brow, there is a visible connexion and harmony. He exhibits a calm colossal vigour of intellect, such, as we have reason to believe, was the character of the living man. "On looking at this noble statue," says Allan Cunningham, "the worthy image of one of the loftiest of human beings, we may ask with the Poet of the Seasons, when dwelling on the greatness of Newton's discoveries, and pointing out the wondrous harmony of their combinations,

"'Did ever Poet image ought so fair!'"

Chantry has expressed the following opinion of it—"The Sir Isaac Newton is the noblest, I

think, of all our English statues. There is an air of nature and a loftiness of thought about it which no other artist has in this country, I suspect, reached. You cannot imagine anything grander in sentiment, and the execution is everyway worthy of it."

Next in succession comes THOMAS BANKS, whoses culpture of Cupid fondling Psyche, is most classical and attractive—a subject so much in request, that hundreds are manufactured and yet the market is never overstocked. Banks was desirous to introduce a more poetic style of art into our national monuments, but he was growing old before his wish was gratified; and it would have been no worse for his fame, if that had never happened. Banks was employed by the East India Company, to erect the Monument to Sir Eyre Coote in Westminster Abbey—and by the Government "Committee of Taste," to erect Monuments to Captains Westcott and Burgess in Saint Paul's Cathedral. There is a great want of variety in these three allegorical Monuments. Victory appears thrice—she raises a trophy—she presents a sword—and she crowns with laurel. All is plain and simple, yet with so few figures, no sculptor ever contrived to give more offence.

The two naval officers are *naked*, which destroys historic probability. It cannot be a representation of what happened, for no British warriors go naked into battle, or wear sandals or Asiatic mantles. As little can it be accepted as strictly poetic, for the heads of the heroes are modern and the bodies antique. Everyday noses and chins are supported on bodies moulded according to the god-like proportions of the Greek statues. Next, certain grave divines took offence at the small line of drapery which drops over the shoulder of Captain Burgess, and Banks added a hand-breadth to it with no little reluctance. When clergymen declared themselves satisfied, the ladies thought they might venture to draw near—but the flutter of fans and the averting of faces was prodigious. That Victory, a modest and well-draperied dame, should approach an undrest dying man, and crown him with laurel, might be endured—but how a well drest young lady could think of presenting a sword to a naked gentleman, went far beyond all their notions of propriety.

But Banks had been more successful in earlier life, when he did not attempt *allegory* but followed *nature*. One of the most affecting Monuments in this country, is that which Banks erected in Ashbourne Church in Derbyshire, to the only

Daughter of Sir Brooke Boothby. She was six years of age, and the sculptor has imagined her on her couch asleep, in all her beauty and innocence. "Simplicity and elegance," says Dr. Mavor, "appear in the workmanship—tenderness and innocence in the image. On a marble pedestal and slab, like a low table, is a mattress, with the child lying on it, both in white marble. Her cheek, expressive of suffering mildness, reclines on the pillow, and her little fevered hands gently rest on each other, near her head. The delicate naked feet are carelessly folded over each other; and the whole appearance is as if she had just turned in the tossings of her illness, to seek a cooler or an easier place of rest." The Monument is very affecting, and awakens maternal feelings deeply. This simple Monument has done more to spread Banks's fame through the island, than all his classic compositions.

The liberties which Sculptors sometimes take with their subjects, may be exemplified in the works of Nollikens, who was the contemporary and rival of Banks. Nollikens made a very fine bust of Dr. Samuel Johnson, who wore a wig, and was quite bald; but the Artist disliked the wig, and clothed the head with hair, under the

excuse that it would make the Philosopher look like one of the ancient sages and poets. The bust is a wonderfully fine one, and said to be very like, but certainly the sort of hair is objectionable, having been modelled from the flowing locks of a sturdy Irish beggar, hired for the occasion. The Doctor remonstrated seriously as to the hair, saying, "A man, Sir, should be portrayed as he appears in company." But the Sculptor persisted. It was the practice of Roubiliac to model his heads without wigs, as witness those fine ones of Pope, Bolingbroke, Mead, and Frewin. CHANTRY too has taken the like freedom with some of the chief dignitaries of the Church. Two Archbishops of Canterbury and a Bishop of Durham, who was bald, are standing in his Gallery, without their wigs, to the astonishment of many a sound divine. There is also a Bust of the late Doctor Parr, without his wig, the absence of which produces an extraordinary and somewhat ludicrous effect.

Nollikens' most celebrated Groups and Statues, are, in the Monument of Mrs. Howard, of Corby Castle, the Statue of Pitt, at Cambridge, and the Venus anointing her hair. The Portrait of Pitt was made from a Mask taken after death, aided

by Paintings. It is no discredit to Nollikens that he did not succeed well either with Pitt or with Fox. One was long and lean, the other fat and round. Nollikens stood more in awe than was proper of the express image of the living men. In his hands Pitt inclines to the mean, and Fox to the vulgar.

The Statue of Pitt attracted much attention at the time. It is a little too theatrical in character; the action passes the bounds of self-possession, and clear-headed thought. He is looking with all his might—but that kind of stare is not mental power, any more than muscular vigour. By the judicious use of the University Gown, the more incurable parts of modern dress are concealed, and the Artist has earned the rare praise of having used actual Costume like a Man of Taste. Three thousand guineas were paid for the Figure, and one thousand for the Pedestal.

John Bacon was a very successful Artist. His Statues of Samuel Johnson and of John Howard, were made, indeed, at different periods, but they are conceived in a kindred spirit, and rival all similar works, save the sublime Newton of Roubiliac. They stand, one on the right, and the

other on the left, of the entrance to the Choir of St. Paul's; and the severe dignity of the Philosopher with his Scroll, and the Philanthropist with his Prison Key, countenance the mistake of a distinguished foreigner, who paid his respects to them as Saint Peter and Saint Paul. In order to get rid of the awkwardness of modern dress, the Sculptor has made the head, neck, arms, and feet bare, and thrown a robe over the Doctor, which reaches to the Pedestal, displaying amid the arrangement of its folds, the manly form which it covers.

Flaxman was as distinguished by the purity of his Taste, as by the excellence of his Statues. The Statue of Sir Joshua Reynolds is one of his first and best. The Painter holds his Discourses on Art in his right hand, and the tip of the fingers of his left reaches the top of a pedestal or altar, on the side of which is a Portrait of Michael Angelo. The Statue of Pitt in the Town Hall of Glasgow, exhibits the Costume which Flaxman abhorred. Both man and dress are too real and literal, to excite that loftiness of feeling, which is, or ought to be, the grand aim of noble works of Art. Here is a specimen of Tailor Sculpture—the Capes, Cuffs, Seams, But-

tons, and Button-holes, are all in the way of dignity. Yet some matter-of-fact people may be found, who are best pleased with this literal resemblance—people who are not troubled with imagination, nor look for mental or historic character in the likeness of a distinguished person. These are the folks who admire the Pig-tail of George the Third, accurately sculptured in the Equestrian Statue of that Monarch in Trafalgar Square, and who, whenever they meet with the Academic Robe, quarrel with it, because it conceals the every-day coat and breeches of the man "they well remember."

After having thus briefly noticed some of the best Statues of the most celebrated of our English Sculptors, it will be found somewhat difficult by the contemplation of them, to arrive at any fixed, universal Standard of Taste. There is this difference between the ancient Statues and the modern ones. The former convey their own lessons to the mind, and are in themselves an authority in forming a perfect judgment, and a standard for every thing that is beautiful and correct in taste. Whoever looked upon the Apollo, the Antinous, or the Diana, and did not concede all artificial dogmas of criticism, as in the pre-

sence of a great Master and Teacher, and felt disposed implicitly to receive the principles of Art, as perfect and unimpeachable, embodied in their forms and expressions. In this class of the Imaginative, the Ancients maintain their great superiority, and the Moderns do not pretend to put forward one rival near their throne. There are indeed, very few instances in Modern Sculpture, where the Statue fills the mind with its own thoughts, and teaches the soul whilst it forms the taste. Some few there are, but in general we reverse the order of critical rule, as before described; and now, remembering the principles of Taste, we ask if the Statue before us is executed according to those principles. In the Ancient we receive them *from* the Statue; in the Modern we apply them *to* the Statue; and how many there are that will not bear the test. From these we learn that the extreme accuracy of portraits, combined with the minute details of Coat, Buttons, and Button-holes, produce a poor and mean effect; that the naked body, the enigmatical hieroglyphic, the scanty drapery, the out of date Victories and Virtues, are unsuitable and preposterous. The Sculptor gifted with genius, may safely take Truth and Nature for his guides, and Taste and Imagination for his instructors. There is ample scope in these, without deviating into

remote and fanciful allegory, or wandering from the fidelity of resemblance. A Statue should be like, but the personal likeness should not predominate over the expression of mental character; and the introduction of adventitious drapery may display the skill of the artist, whilst it may overcome the ungainly stiffness of Modern costume. So in landscape painting, the Painter preserves the truth and feeling of the landscape by depicting the light, the shadows, and the *character* of the scene, together with the natural local objects. And by this art the work of genius is distinguished from the dull, formal, and exact outline produced by the mechanical process of the Camera Lucida. The portrait painter also, such as the late Sir Thomas Lawrence, not merely transfers a likeness to his canvas, but combines with it, expression, animation, and grace; until the portrait becomes a memorial of mental qnalities, as well as of individual proportions.

And it is in this way that the Sculptor copies Nature, and so appeals to the affections and sensibility of the spectator. He embellishes with taste and imagination, and thus awakens in the minds of others, ideas of grace, beauty, or genius.

It is after this manner that Chantry, by his

great talent and his cultivated understanding, has enriched his native country by many splendid and touching works of Art. Of the latter kind I will only mention his pathetic monument of the two children in Lichfield Cathedral, where Truth and Nature eloquently, though silently, awaken imagination and sensibility. It is of the same class with Banks' monument to Sir Brook Boothby's daughter, in Ashbourn Church ; and in these monuments, England may be said to possess two of the most touching pieces of Sculpture in the world.

Of the other kind, Manchester is so fortunate as to be possessed of one of Chantry's best works of Art, in the statue of Dr. Dalton. It is sufficiently like, to gratify the affections of his more personal friends, whilst the intellectual qualities of the Founder of modern chemistry, are suitably embodied in marble, so as to correspond with his reputation amongst his countrymen and amongst Foreign Nations. As a favourite work of one of the most eminent of Modern Sculptors, it will always rank deservedly high ; and the fame of our estimable and distinguished President, and that of Chantry, will descend together in this honourable memorial to posterity.

## REMARKS ON THE ORIGIN

OF THE

# BABYLONIAN, OR ARROW-HEADED CHARACTER,

AND ITS

## RELATION TO OUR MODERN ALPHABET.

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By Mr. JAMES NASMYTH.

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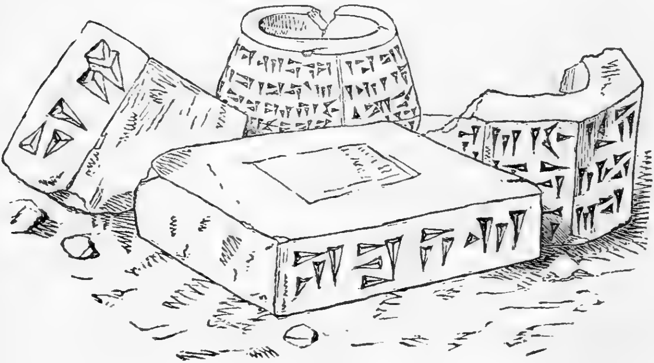
Read 4th of February, 1840.

The halo of deep and mysterious interest which envelopes the mouldering remains of the once mighty Babylon, causes us to look upon the merest fragment of its ruins with a feeling of veneration which is beyond the power of language to express. To so remote a period in the history of man does it relate, that the position which it holds in history may justly be considered as the very last discernable link in the chain of existences; beyond which, all is involved in impenetrable darkness.

This feeling has led to the removal to our museums, as objects of deep interest, such humble reliques as bricks, and fragments of pottery,

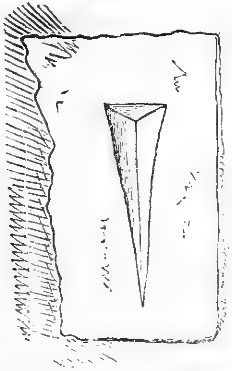
which, being the hand work of a mighty people, who, upwards of four thousand years ago, set the first example in the practice of the arts and cultivation of the sciences, and thereby made the first great steps toward civilization, cannot otherwise than excite feelings of the highest veneration. Besides these considerations, the interest naturally attached to such fragments is indeed vastly enhanced by the fact of their being, for the most part, covered over with certain alphabetic characters, whose most striking and peculiar appearance at once attracts our attention. The annexed figure may perhaps serve to convey an idea of the general appearance of such bricks and fragments of pottery, as are alluded to above.

FIG. I.



It will be observed, that these peculiarly striking alphabetic characters, are all composed of certain combinations and arrangements of one simple elementary form (as represented at figure 2) which from a certain similarity or resemblance has been termed the *arrow-headed character.*

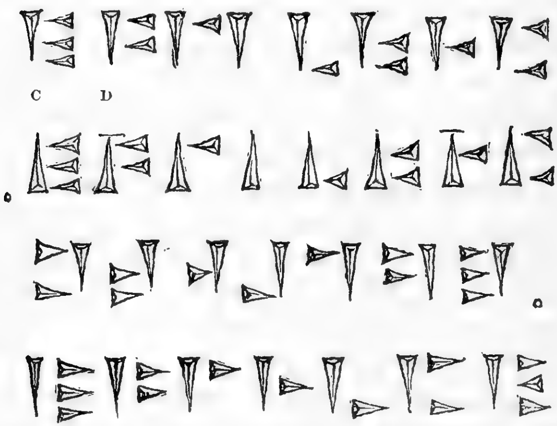
FIG. II.



Simple as this elementary character is, it will easily be perceived that it is admirably adapted for the purposes to which it was applied, namely, the formation of an alphabet; in as much as it is a form at once striking and peculiar in its appearance, and, as will be shortly explained, admitting of a remarkable facility of production—and above all, capable of being united and so arranged as to admit of an infinite variety of combinations, as

may be seen on inspecting those given in Fig. 1. or in Fig. 3., when by simply leaving out one or other parts of the first combination in a certain order, as in B. or simply reversing the position of one of the elementary arrow-heads, as at C. D. we are able to repeat the entire series again.

A B FIG. III.



Here we have thirty perfect alphabetic characters, every one of which is distinctly different, and yet we have only *three* transpositions of the elementary arrow-head, as may be seen by a very transient glance at the preceding figure; these distinct combinations might be pursued without end by the system of making changes in the relative position of the elementary forms, for by sim-

ply reversing the position of the upright arrow-head, as in C D, into the position as given in A B, we have a new series at once, and strikingly different from the other. I shall not dwell further on this part of my subject, as I trust it is sufficiently evident that this simple elementary form, *or single arrow-head*, might, as doubtless it did, become the foundation of a most perfect and extensive alphabet, admirably adapted for the use of a primitive people, who had day by day numbers of ideas brought into action, inasmuch as being without the assistance of any accurate scientific knowledge, whereby they might be enabled to reduce to system and so classify their observations on the ever-varying terrestrial and celestial phenomenon, (of which, however, as the very first and earliest recorders of such facts, they ought to stand most high in our veneration) it would be on this very account (namely, the multitude of apparently distinct ideas created by an unsystematized observation of the phenomena of nature), that they would require an almost infinite alphabet to enable them in that rude way to express by such conventional process, their numberless observations. This, however, is somewhat speculative, and not immediately bearing upon the subject. I may, however, ere I leave

this part of my paper, make one remark on the truly interesting fact, that we have in this instance the invention or creation of a *perfect alphabet*, namely one whose characters are of a purely elementary nature, that is to say, having no reference whatsoever to the likeness to any natural object, which circumstance draws a very important line of distinction between it and that of the Egyptian, which is of a hieroglyphical or symbolical nature, and has, therefore, a *graphic basis* or origin, namely the attempt to express or convey the idea of an object by a representation of it more or less faithful; in the case of the Babylonian arrow-headed characters, however, we have no such resemblance; it is, therefore, purely alphabetic. This might strike the key of a very interesting investigation, and perhaps be shown to have been one of the results of "the confusion of tongues," which it is more than probable Babylon was the scene of.

I shall now proceed to make a few observations on what appears to me to have been the most probable cause which has led to the adoption of the arrow-headed character as the basis of the Babylonian alphabet, which may prove the more interesting to my readers, as the observations I have

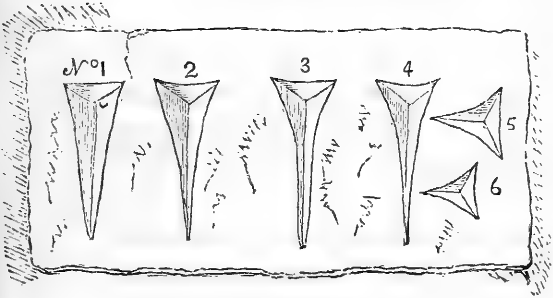
to make may tend to illustrate one of the great fundamental principles in the investigation of what may with propriety be termed "*the etymology of forms*"—a most deeply interesting subject, and one on which "the philosophy of architecture" is founded—namely, the tracing back to their primitive origin those forms which serve to distinguish one style of architecture from another. I trust I shall be able to show that the present subject is a most striking and beautiful illustration of principles just alluded to, as well as exhibiting in a most marked manner that tendency which mankind have ever had to cling to, and so perpetuate certain forms, which were natural to the materials that were employed, as being most convenient and suited to the wants and capabilities of the nation, when in its primitive condition.

In tracing back to its primitive origin the architectural style of any nation, in any degree celebrated for the cultivation of the arts, we shall find that in almost every instance the character of the style in question, has a distinct reference to the nature and capabilities of that material which was most abundantly and conveniently situated to supply their primitive wants, in reference to the erection of such buildings as they required for their domestic or religious rites.

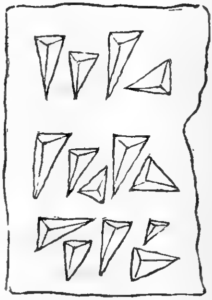
It was these considerations which led the primitive Babylonians to employ mud and clay as their chief building material, having established themselves on the banks of the Euphrates. The entire soil of the country adjacent, furnished them with a material, which simply by the heat of their all-but-tropical sun, became sufficiently indurated so as to be capable of being employed on the most extensive scale for their buildings; *hence they became a great brick-making* people, the truth of which statement requires no proof; it is to the fact that the Babylonians practised the art of brick-making, that I hope to show that the arrow-headed character has its origin.

I must now proceed to investigate the nature of its form, and the mode employed for its production, which will lead me to its probable origin, which latter consideration being of a speculative nature, I shall touch upon last. As to the mode by which it was formed, the evidence I have to bring forward is of such a satisfactory nature that I trust I shall clear away every doubt from the minds of my readers.

FIG. 4.




No. 7.



The above figures represent the only varieties of the arrow-headed character which I have as yet met with: all of them embody the chief features, namely the triangular form; and, above all, I would beg to draw attention to what I term *the depressed angle*, the more so as I shall have occasion to refer to it again as I proceed. This depressed angle is what I consider as one of the chief features in the form of the arrow-head character, which I consider to be due to, and to have distinct reference to, the nature of the material in which it was chiefly written or inscribed, or, more properly speaking *impressed*, as well as the means by which it was produced. I have marked this depressed angle in No. 1, Fig. 4, with a small O; in all of them the same characteristic feature is observable.

No. 1, is the primitive form of the character, the sides being all straight lines.

No. 2, an after variety, where the sides are composed of curves.

No. 3, another variety, in which the tail of the character is lengthened out.

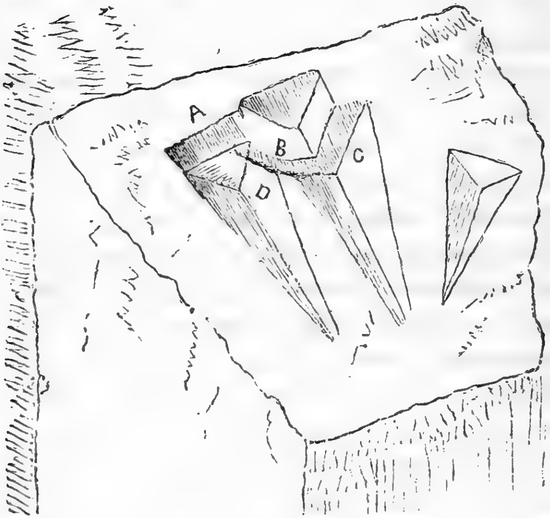
No. 4, a character combined with varieties of the short arrow-head, as seen in No. 5, 6.

All of these, including No. 7, I believe comprise every variety met with in Babylonian remains, the depressed feature is general throughout. It was this consideration which led the author to inquire within himself, by what means was this singular character produced? The very question involves the answer—It was produced by the depression of the corner or angle of any cubical or triangular prism, such as the corner of a square stick, or angle of a three-cornered prismatic style. The instant this idea presented itself in reference to the moist state which the clay must have been in when these characters were impressed on its surface, the whole became clear, and the manner of production was as evident and distinct as if he saw the Babylonian brickmakers impress the arrow-head. It was while spending a delightful forenoon in the British Museum some nine years since, that this idea occurred to the author: and having thus hit upon so happy an idea of the

mode by which these remarkable characters were formed, he rested satisfied of the correctness of his conjecture, until, about seven years after, on again revisiting the same noble institution, and recurring to the Babylonian bricks, of which there are a great variety, he was so fortunate as to discover one in an obscure corner, on the edge of which (it being a very large brick) to his great inward delight he discovered among some very bold and deeply indented arrow-heads, one in which the brickmaker had some 4,000 years ago *pressed his style so deeply into the (then) soft clay, that it had left the very size, as well as the form of the end of the style*, in the clay, and thereby transmitting to us a truly solid basis whereon to prove the correctness of the author's theory of the manner in which the arrow-head character was originally produced.*

* It may be as well to remark that the arrow-headed character is of such a nature, as regards its facility of production, on the surface of any soft substance, that on that account it would be admirably adapted for the system of writing on tablets of *wax*, which was so frequently applied or used for such purposes, as appears by the writings of many ancient authorities. The perishable nature of that material has doubtless prevented us from having ocular demonstration on the subject, so that I only throw out the idea as a probability. The arrow-head is *certainly a clay character*, although, as we shall see shortly, it was applied to other materials by the chisel, &c., &c.

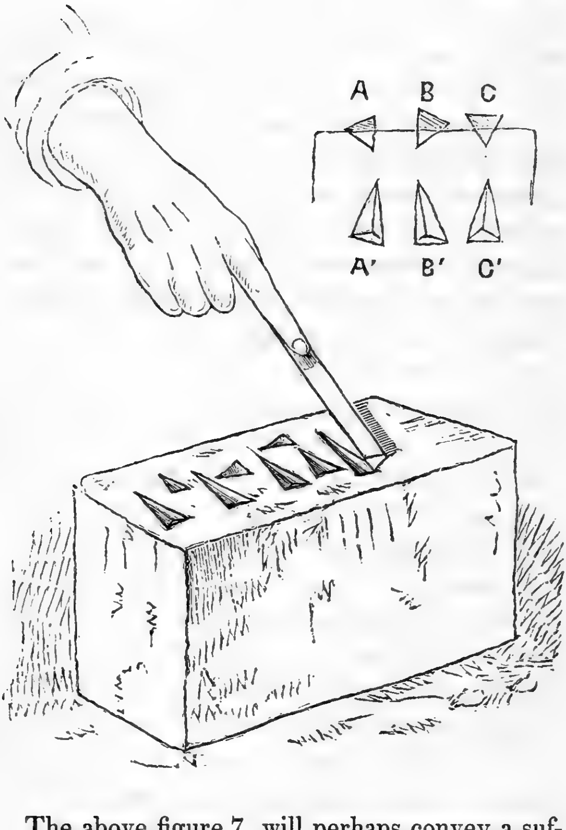
FIG. 6.




The above figure represents the part of the brick just alluded to, in which it will be seen that at A there is a straight down part, which indicates the quantity of *more than sufficient* depression, while the triangular form immediately under the flat part at A, is the absolute fac-simile of *the form and size of the style* by which the character was produced—*it has been a triangular style.* So absolutely faithful and distinct is this fortunate and deeply interesting remain, that it is quite

possible to tell that the brickmaker impressed the character B, after forming A and C. This is most clearly proved by a little flap of clay, which is seen hanging over into A at D—a result due alone to its having been impressed last of all. This simple, but interestingly beautiful detail, tends in a striking manner to illustrate the importance of minute practical observation in such investigations; it even conveys to us the knowledge of the exact state of moisture in which the clay was when so impressed, as before said, upwards of 4,000 years ago!

FIG. 7.



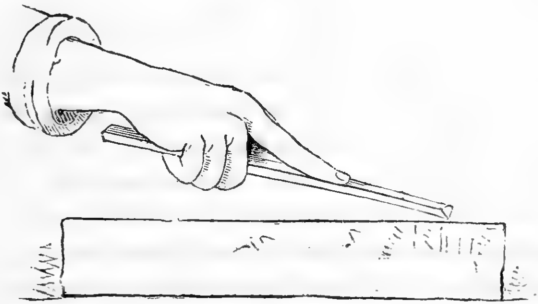

The above figure 7, will perhaps convey a sufficiently distinct idea of the mode in which the

triangular style was used in producing the arrow-headed characters, as alluded to in the preceding remarks. That it was a three-sided or triangular style, as given above, there can be no doubt, as that question is set at rest by my having discovered an absolute impression of its extremity, as seen in Fig. 6, at A. The reason for a triangular style being employed, may be found in the much greater convenience which such a form would present, inasmuch as any one of the three corners might be employed, and yet produce exactly similar characters, while the flat surface, or side next the finger, would not only serve as a convenient surface for the finger to press the style into the surface of the moist clay; but moreover, this same flat surface would at all times serve to show the operative, or brickmaker, when his style was correctly placed with respect to the surface of the clay, which is a point of much importance in the production of perfect arrow-head characters, inasmuch as were this not attended to, and the style brought in contact with the surface of the clay, in an inclined position, either to the right or left—as at A or B, Fig. 7, instead of as at C—we should produce characters by no means so correctly formed as those generally met with in Babylonian inscriptions, whether on bricks or pot-

tery, in which latter case, however, I have observed some characters evidently produced after the manner of A or B, namely, when the character is considerably off at one side, either to the right or left hand; and such occur in combination with those of the more regular form, so as to lead me to suppose that they might have been so produced intentionally different to the other, so as to stand for some conventional character similar to our system of punctuation in orthography. It will be also worthy of remark, in reference to the manner in which the three-sided or triangular style of the Babylonian brickmakers was used, that by means of the same simple instrument not only could an infinite variety of letters be produced, but also *any variety in the size of the characters*, simply by the greater or less amount of depression of the style into, or under, the surface of the moist clay, the proportions of the characters being in all cases the same, whatever might be the size, which is also one of the many beautiful properties of this admirable system of inscription; besides which the inclined position of the hand and style, with regard to the surface of the clay, which position is absolutely requisite in the production of these characters, renders the hand clear from any accidental contact with the

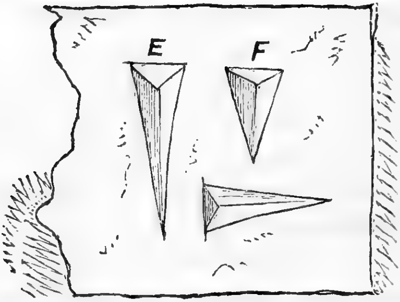
inscriptional surface, and all risk of obliteration is removed, as may be seen in Fig. 8.

FIG. 8.



It will be seen here that the inclined position of the style, with regard to the surface of the clay, is not only absolutely essential to the production of the arrow-headed character, but is also, as before said, most convenient and natural, at the same time, the length or shortness of the characters were determined and varied at pleasure, simply by inclining the style more or less with respect to the surface of the clay; a slight inclination producing a long character, as at E, (Fig. 9), or short, as at F; such varieties being required in the production of the various letters, or as in case of punctuation or other conventional signs.

FIG. 9.




Ere I conclude this part of my subject I may as well say a few words on the mode in which the style has been used, in order to produce the varieties given in Fig. 4, at No. 2, 3.

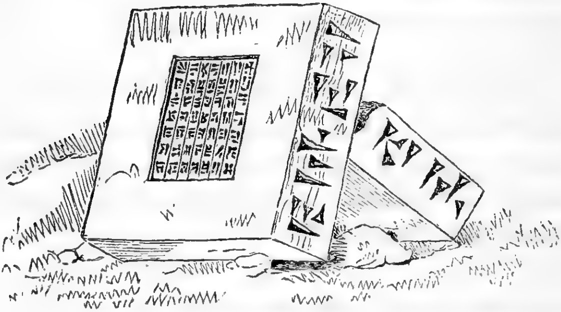
With respect to the manner of producing the variety given at No. 2, when the sides of the character are curved slightly, as will be seen on inspecting the figure alluded to, this was simply the result of the style being slightly turned over to the right and left side before being lifted or raised from the surface of the clay, while, at the same time, the style was inclined rather more than what had been requisite to the production of the simple straight-sided character, No. 1: by this most simple action this beautiful variety is produced, the very mode just described being such as

would naturally assist in facilitating the removal of the style from the surface of the clay.

With regard to the variety, No. 3, it was simply produced by trailing or drawing the point of the style towards the inscriber or brickmaker, which simple action would instantly produce the tail which distinguishes it from the others.

Having thus alluded to the manner in which the Babylonians produced the arrow-head characters on their bricks and pottery, I shall, ere I pass on to the concluding part of my subject, make mention of the mode by which they impressed the *sides* of some of their bricks with certain tablets of characters, which doubtless was a system introduced *after* the invention of "the style produced" character; namely, that which we have been hitherto describing, where each individual elementary or single arrow-head is the result of a separate and distinct impression of the style of which I need only refer my readers to Fig. 6, which I consider as of the highest value in support of the truth of my discovery; namely, as to the mode originally employed in the production of these singular characters.

FIG. 10.



The annexed Fig. 10 represents one of those bricks, on the side of which a tablet of arrow-head characters is impressed; that such tablets have been the result of the impression of an engraved block or die there can be no doubt, from the fact that the tablet or border around them is depressed *below* the surface of the brick, that being the natural result of an impression produced from an engraved block or stamp, in which the characters had been carved in the natural manner. Could there be any doubt on this subject, *the absolute identity* of such tablets on several bricks would, I imagine, clear it away. The depressed frame or border to the tablet is the result of the force with which the stamp was caused to act upon the surface of the clay. I have never found any of those impressed tablets on any other part than the *side* of the

brick. On most of such we find the *style* characters on the *edge*, as seen above; that situation being best adapted to enable the inscription being seen when the brick was placed in the wall—that on the side being hid, as a matter of course, and only existing as a record to be brought to light on the destruction of the building. It may not be out of place to remark here how very near the Babylonians came in contact with *the art of printing*, in their stamping a page of inscriptions at once, and in the manner of *stereotype!* also.

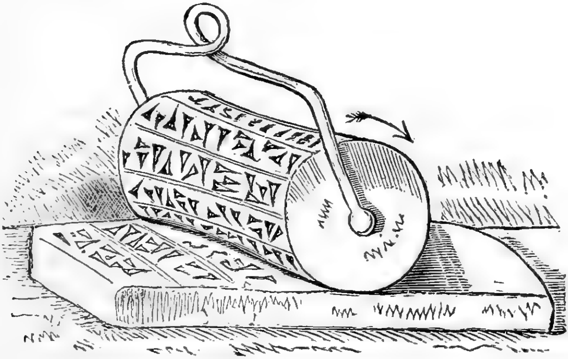
The next stage in the history of this remarkable alphabetic character, is that in which we find it occurring on *other* substances than that which we may so properly consider as its native one, namely, *clay*. In many Babylonian and Assyrian remains we find that this singular character occurs in conjunction with sculptures in marble and other stones, on all of which, however, it preserves with singular faithfulness all the characteristic features which are inherent and natural to it in the case of clay, namely, the triangular form, and above all, the depressed angle. See Fig 4, No. 2, or Fig 4, No. 1, at *o*. The only slight variety is that of the curved side, which we have explained might have been introduced as an embellishment,

and might have been derived from the clay character, in which the style had been rolled slightly from side to side ere it was lifted from the clay. Several slabs or tablets of marble, and other stoney material, exist in the British Museum, which are covered with inscriptions in these beautiful and striking characters, all of which are the result of the *chisel*. Here then we have an illustration of that important principle in the philosophy of architecture, namely the tendency which mankind have ever displayed to cling to certain forms, which however natural and due to the materials, the employment of which led to their adoption, have (yet in the case of marble or stone) no natural reference to the form in question. The arrow-head is essentially a *clay* character, and its transference to stone is the course due to its adoption as the conventional or alphabetic character of the people who employed it, and who would be the more induced to adopt it as their alphabet, inasmuch as it was possessed in so very remarkable a degree of all the great and important requisites, namely, its capability of infinite combination, together with its great facility of production, whether by the style in clay or wax, or by the chisel in marble or stone, and even in precious stones and others, such as cor-

nelian, agate, and other similar materials, as we find in the case of those singularly beautiful Babylonian cylinders, by the rolling of whose engraved surfaces over clay or wax, impressions such as used on seals, were produced, in a most perfect manner, as indicated in Fig. 11.

BABYLONIAN CYLINDRICAL SEAL ROLLER.

FIG. 11.



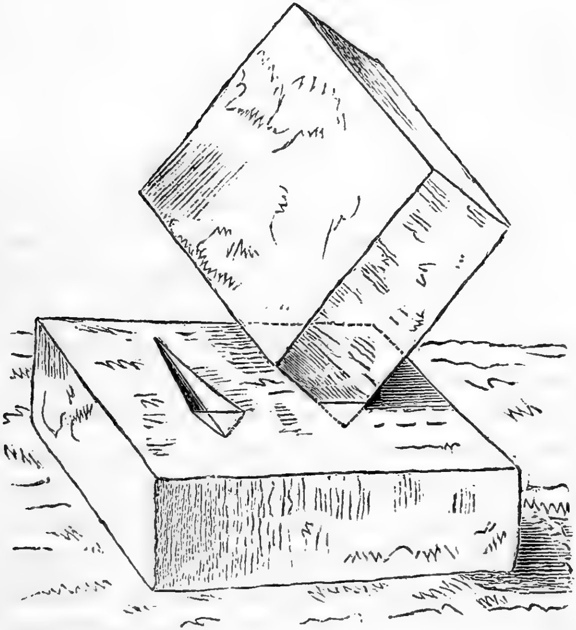
The mechanical principles inherent in this beautifully simple form of seal roller, indicate a very high order of ingenuity, well worthy of the originators of the arrow-head, inasmuch as by engraving the inscription or device on the surface of a cylinder, they were enabled in a very small compass to include a very considerable surface of seal; and, above all, as such a cylinder would, in being rolled over the surface of the clay or wax,

come in contact with it as it were line by line, a very slight pressure would in this way produce an effect in the way of impression, which in the case of a seal, whose flat surface was equivalent to that of the cylinder, would require a very considerable force to produce the same effect. This simple principle practised upwards of 4000 years ago, includes the entire theory of the action of rollers, as employed in pressing or extending materials.

Ere I leave this part of my subject, namely, the modes by which the arrow-head characters were produced originally in *clay*, by the style, and subsequently in stone and marble by the chisel, I shall now offer a few remarks by way of conjecture as to the manner in which the first idea of this truly beautiful and remarkable character suggested itself to the primitive brick-making Babylonians. What I have to offer on this subject I am perfectly willing to admit, is open to attack, as being over fanciful and highly speculative. Be that as it may, my readers shall have my ideas on the subject, and they may receive or reject them as best pleases their own fancy; for as I am in possession of no absolute fact whereon to found my views in regard to *this* part of my subject, I must fall back upon probabilities; and

truly glad shall I be to abandon what I am about to state, whenever I find any theory which has a better foundation than that of conjecture, but until then it is better to have some ideas on the subject before our minds than none at all.

FIG. 12.



The above figure will perhaps serve to explain my ideas as to the probable origin of the Baby-

lonian arrow-headed character. That it is intimately connected with bricks I trust what I have endeavoured to set forth in former pages, will in some degree substantiate: it is simply by following out the ideas in connexion with bricks and moist clay, that I am induced to submit to the attention of my readers the above figure, illustrating the probable origin of this remarkable character. Let us only for a moment suppose that a hardened or dry brick falling on some one of its angles, either intentionally or by accident, impressed or indented its corner into the side of a soft or undried brick, as represented above, what would occur? and what would be the form and appearance of the mark so produced in the side of the soft brick by the angle of the hard one? *Nothing more or less than a most perfect arrow-head!* having all and every characteristic of those actually found on the bricks of Babylon, the size and proportions depending of course upon the force and inclination of the falling brick, as it came in contact with the other. That such an action of the corner of a hard brick on the surface of a soft one, DOES produce an arrow-headed character, with all its striking and remarkable characteristic features, there is no room for doubt, as I have put it to the test of experiment; and

more nice and faithful characters could not be produced by a veritable Babylonian style than that which results from this truly simple and primitive mode, which although originating by accident, might afterwards have been intentionally employed in marking (as is the practice to this day) certain lots of new made, and consequently, moist bricks; the practice in our own time being the insertion of a chip of wood, or small stone, into the side of the soft brick, which marks a certain lot, whereas on the banks of the Euphrates, in the remote days of the primitive Babylonians, the more simple mode of marking might have been such as seen in Fig. 12, namely, by indenting the side of the soft brick with the corner of a hard one, the result being, as before stated, a most perfect arrow-headed character—in this way the arrow-head might have existed, and been employed simply as a conventional sign or mark as to number, and afterwards, on being seen by some fertile mind, its admirable qualities might have been appreciated, and its wonderful capabilities of combination thenceforth applied, so as to become, as it certainly did, the fundamental or elementary character of the entire Babylonian alphabet, and—as I hope to prove to my readers likewise—the basis of the Greek, Roman, and

modern capital alphabet, whose descent from this truly venerable character I trust I shall be able to prove in so clear a manner as to confer the highest degree of interest on the foregoing investigation, which in that view of the subject cannot otherwise than reflect back the deepest interest on the origin and nature of a character, which is not only the most ancient we are acquainted with, but also as being connected with the most remarkable eras in the history of mankind and the progress of civilization.

With respect to the preceding remarks, as to how it is possible the accidental indentation of the angle of a hard brick into the side of a soft one, might have given the first idea as to the employment of the remarkable character so produced, to become the elementary or fundamental form whereby to originate so wonderful an alphabet, my ideas on this part of my subject, I must confess, admit of the charge of speculativeness, inasmuch as I have no other basis whereon to form my remarks than probability or conjecture. I do not desire to build any theory on this part of the subject, the more so, as in all other respects I trust what I have brought forward, and have yet to advance, is based on such incontrovertible

facts, admitting of ocular and tangible demonstration, that I am the more anxious that a line should be drawn by my readers between what is merely a conjecture founded on probability, and that which is derived from undoubted historical facts, and capable of proof, by reference to the aetual bricks themselves, in which the mark of the style is as distinct as if it had been the production of a few weeks since, in place of upwards of 4000 years! for proof of which refer to Fig. 6.

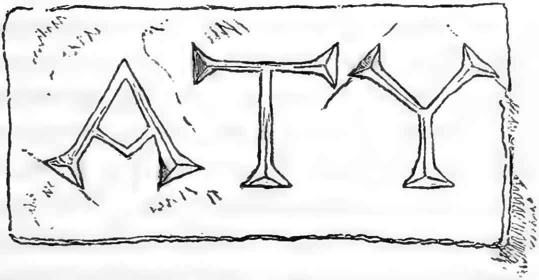
I now come to what appears to me to be the most truly interesting portion of my paper, namely, the proving that the Babylonian arrow-head character is the prototype or original form from which the Greek alphabet is derived; and hence, as a matter of historical sequence, that also of the Roman and British capital alphabet, in the form of whose letters I expect to show my readers that there still exists the evident remains of its Babylonian origin!

It was while engaged in the rapid investigation of the manner in which the arrow-headed character had been produced, and its general nature and capabilities, that the idea occurred to me that I might have some light thrown upon the historical

tradition as to Cadmus having brought over from Tyre, and subsequently taught the primitive Greeks their alphabet, which at that early period consisted of sixteen capital letters, to my inexpressible delight I found, on reference to some of the most ancient Greek inscriptions in the British Museum, that most of the capital letters were composed of absolute elementary arrow-heads! The source from whence the primitive Greek alphabet was derived, at once substantiated *historically* the conjecture I had formed. Cadmus was from Tyre, being a Phœnician, and skilled in the learning of the Chaldeans, who were the most enlightened and learned of the Babylonians; hence it is, that historically speaking, we ought to find an arrow-headed or Babylonian feature in the characters which he gave to the primitive Greeks as their alphabet. That this is the case, we have only to refer to any ancient Greek inscription, which we shall find to abound with ocular demonstration of the most substantial description, as may be seen on reference to the figure annexed, which is a most careful and rigidly faithful representation of some of the letters comprising a most ancient Greek inscription now in the British Museum, among which there exists numberless examples, all of which bear out in

the most clear manner the theory which I have advanced, and of the truth of which I am about to submit ocular proof.

FIG. 13.




The above, Figure 13, is a faithful representation of three capital primitive Greek alphabetic characters, in the formation of whose details the elementary arrow-head is most marked and strikingly evident, any one of them being capable of resolution into its primitive element, namely, the single arrow-head, which, I trust, is so evident as to require but little proof otherwise than that of ocular demonstration. I shall beg to draw attention to what appears to me to be the most clear and important evidence in respect to the relationship existing between these Greek letters and their Babylonian prototypes. What I allude

to here is the *non*-parallelism of the bottom stroke of the character A with the line of the inscription, or as seen in Y, the top strokes of whose upper parts are seen to incline very considerably out of line with the inscription. I would request most particular attention to be paid to this fact, as it carries with it the most simple, clear, and striking evidence of the Babylonian, or arrow-headed origin of these characters, each of which may be resolved into its elements, and these elements being a simple arrow-head. So faithful, indeed, is the arrow-headed character kept up in those Greek capital letters, and indeed in almost all others, of whatever size, that we find the *depressed angle* before alluded to in Fig. 4, No. 1, most carefully given; and in every case this is attended to with the most scrupulous accuracy—a circumstance the more remarkable, considering the vast length of time which elapsed between the period when the arrow-head character was first employed by the Babylonians, and that of the arrival of Cadmus in Greece, a period not less than 1800 years, thus tending to illustrate in a striking manner what was alluded to in a former part of this paper, namely, *the tendency which mankind has ever had to cling to forms, which, however due to the nature of the material, to the*

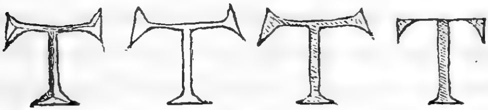
*use of which they owed their origin, yet had no natural reference to the materials in conjunction with which we now find them;* for here in the characters seen in Fig. 13, we have the triangular form of the style produced arrow-head, together with the depressed angle, which is a feature due to and inherent in the Babylonian arrow-head, as being the result of the impression of the angle of the style in the soft clay. *See Figs.* 6, 7, 8. I could crowd my paper with further examples derived from ancient Greek inscriptions, all of which would, in the most perfect manner, substantiate what I have set forth in Fig. 13, and the remarks thereon. I trust, however, that the examples brought forward will be sufficient to make good my alleged discovery of the existence of ocular proof of the Babylonian origin of the form of the Greek *capital* letters. I lay a stress on the word capital in order to draw a line of distinction between them and the smaller characters, which being the result of the use of a pointed style on wax, or a pen with ink, bears, on the exact same principle as that of the arrow-head, a form which is due to and directly referable to the instrument or means employed for their production. I would beg this to be carefully kept in mind, as when so considered the forms of such small

non-capital letters tend rather to illustrate one of my important positions rather than controvert them, the capital letters having reference to the use of the style in clay, while the others have reference to the pen and ink.

Once having established a connexion between the forms of the Greek capital *inscriptional* characters and those of the Babylonian or arrow-head, it follows as a matter of course, by direct sequence, that the Roman alphabetic characters owe their primitive origin to the brickmakers of Babylon ; for what is true of the Greek is, as a mere matter of consequence, true also in regard to the Roman, in every one of whose inscriptional characters the arrow-headed origin is traceable, and most clearly evident, the only observable difference being a gradual although slight deviation from the non-parallelum of the bottom stroke of the letters, which become, very nearly, and in most cases, quite in line with that of the inscription, of which it is not requisite to furnish any figure, as that of No. 13 will convey what I allude to as to the existence of the *non*-parallelum in the case of the A and Y. Reference to any of our modern capital letters, will substantiate what I have endeavoured to set forth and prove, namely,

the existence of ocular demonstration as to the Babylonian origin of the Greek, Roman, and, consequently, modern capital alphabet, to which, of course, I may add such nations of Europe as employ classic characters. It is truly singular and highly interesting to observe the gradual departure from the original Babylonian character in the letter T, the transition or modification in whose form is comprised within the last 350 years, in which time, if we take an example from any old book at any of the intermediate periods, we shall find the gradual departure from the primitive form, which we endeavour to represent below.

FIG. 14.

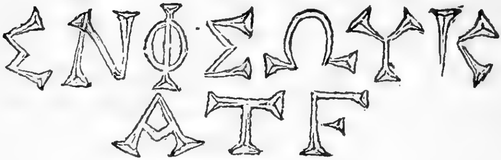


300 B.C. to A.D.1500. A.D. 1500 to 1630. A.D. 1630 to 1770. A.D. 1770 to 1840.

The above may serve to exhibit the gradual passing away of the *arrow-head features*, as evinced in the form of the letter T, with which more liberties have been taken than any other letter, all of which, however, retain the arrow-headed characters, more or less faithfully.

Thus have we a most striking example of the interest which beams forth from objects of the most familiar kind, when viewed in their proper light as regards their *etymology of form.*

FIG. 15.



The above rude letters are selected from an ancient Greek inscription, in which the arrow-heads are very distinct, the depressed angle in all being cut with great care, and in that respect most distinctly indicating the arrow-headed origin. In respect to those letters in which we find the circle employed either wholly or in part, we can in all such cases trace the arrow-head, such for instance as seen in the case of the *Omega* above, it being compounded of a portion of a circle with two very distinct arrow-heads at each side; in short, so absolutely is this discovery as to the Babylonish origin of the *form* of the Greek, Roman, and modern classic alphabet, borne out by fact, that we have but to look at any of our

modern alphabetic capital letters, to find the most distinct ocular demonstration of the truth of what I have brought to light.

Thus have I endeavoured to lay before my readers the progress of an investigation which has afforded me very high gratification; and I trust I have made myself sufficiently understood as to enable any one who may take a similar interest in such subjects to refer to the objects to which I have alluded, namely, the Babylonian, Greek and Roman antiquities in the British Museum, or in any other similar institution in which such interesting objects exist. Having given the *key* to their form as to the Babylonian or arrow-head origin, it becomes at once evident, and any ancient or even modern inscription, will supply the most satisfactory and substantial evidence.

I have never in any of my investigations in the etymology of *forms*, found an instance which so perfectly embodies the principles of such interesting researches. To be thus able to trace through upwards of 4000 successive years the origin, rise, and progress of the *form* of such mighty yet beautifully simple agents of civilization as that of our alphabetic characters, commencing

from the first impression in clay, with the corner of a stick, either by intention or through accident, and to trace their progress from year to year, from age to age, and from nation to nation, and yet to find the primitive form shining forth, and carrying the mind back to the banks of the Euphrates, where civilization had just begun to dawn on the Eastern world, and to find that such a simple origin had kept the integrity of its character through so vast a span of ages, cannot but suggest to the mind a series of reflections teeming with interest of the most striking and peculiar nature, inasmuch as we may thus retrace the progress of our alphabet from our own times backwards step by step, until we reach a period in the history of man so near to that of his own origin, that we all but arrive at the very zero of research.

I shall not fatigue the attention of my readers with any further remarks, trusting the rest to their own reflection, which will doubtless be of a gratifying and interesting nature, provided that they are satisfied with the correctness of what I have advanced; and as I have stepped from *fact* to *fact*, and have begged them to refer to the sources and objects which have supplied me with the data

of my discovery, I now beg to leave the matter in the hands of those who will take the trouble to test its correctness, by all and every means in their power, and to let the discovery stand or fall as they think proper. I now bid farewell to my subject in this form, with the hope that I have not fruitlessly spent my own or their time.

AN

# EXPERIMENTAL INQUIRY

INTO THE

## Strength and other properties

OF

# ANTHRACITE CAST IRON,

BEING A

CONTINUATION OF A SERIES OF EXPERIMENTS ON BRITISH IRONS, EROM VARIOUS PARTS OF THE UNITED KINGDOM.

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By WILLIAM FAIRBAIRN.

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Read 17th November, 1840.

In March, 1837, I laid before the Society a detailed series of experiments on the strength and other properties of cast iron, collected from the different works in Great Britain. Since that time a description of iron, entitled anthracite, has been introduced into the market. The name anthracite was first applied to carboniferous formations by the French; it is derived from the Greek word *anthrax*, coal. The iron is made either wholly or in part from anthracite fuel, and in most cases the best qualities are obtained from the raw coal alone, excited by the hot blast.

At some of the Welsh iron works, coke and anthracite coal in certain proportions have been tried, and at others a mixture of bituminous and anthracite coal; but in almost every instance, I believe, the products have been of an inferior quality, and it is only since the introduction of the hot blast that anthracite coal alone has been rendered available in the reduction of the ores. It is now, however, generally adopted in the anthracite districts, and several works have recently been erected for the manufacture of iron by this new process.

Before entering upon the examination of the specimens experimented upon, I would first premise a few observations on the nature and properties of the fuel from which they were produced.

Mr. W. R. Johnson, Professor of Chemistry and Natural Philosophy, of Pennsylvania College, Philadelphia, has paid great attention to this subject, and by a careful analysis of the American coal, has given the products of the anthracite formation, as found in Luzerne county, Pennsylvania. The American anthracites so nearly resemble those of our own country, both as regards their properties and appearance, that I shall, before concluding this part of the subject, make a

few extracts from Professor Johnson's inquiries, in order to compare them with similar carbonaceous deposits found in the Swansea basin, and other parts of South Wales. In the latter districts, as at Aberavon, Hirwin, &c., the beds of anthracite alternate with the bituminous formations, sometimes composing the uppermost strata, but in most cases underlaying the bituminous coal. In some positions they pass into very thin laminæ, and in others, the layers are so intermixed as to form the coal *en masse.* They, however, vary in quality, according to the district where they are found. The lower veins of the Bute colliery, at the Hirwin and Plymouth iron works, according to Mr. Mushet, are partly anthraciteous, containing a greater or lesser degree of anthracite matter, accompanied with certain proportions of bitumen or carburetted hydrogen.

The coal at the Yniscedwyn and Ystalyfera works, in the Swansea valley, is entirely anthracite, containing nearly the same proportions of carbon as are exhibited in Professor Johnson's experiments on the American specimens.

The purest Welsh anthracite coal, such as the Yniscedwyn, Ystalyfera, and the lower stratum of Neath Abbey, contains about 90 per cent of

carbon, and the remaining ten parts are composed of carburetted hydrogen, carbonic oxide, and some earthy matter. Out of two specimens sent me from the Ystalyfera works, the following results were obtained—

| | |
|---|---|
| Loss at a red heat, yielding a little carburetted hydrogen ............ | 5.4 |
| Ashes, greyish white .............. | 4.6 |
| Carbon ................................ | 90.0 |
| | 100.0 |

From this description of fuel, we derive the best qualities of anthracite iron.

At the iron works of Vezille, in the canton of Launure, near Grenoble, large sums of money (500,000 francs) were expended in the construction of works, and in making experiments for the fusion of the earthy carbonate of iron, by the anthracite of Launure. These works were in progress from 1824 to 1828, when they were abandoned, the proprietors being no longer able to contend against obstacles which seemed insurmountable. Many interesting results were nevertheless obtained from the experiments made at the time.

The ashes of this anthracite gave the following

constituents, the analysis being a mean of experiments on a large quantity:

| | |
|---|---|
| Silex | 58.4 |
| Alumina | 40.0 |
| Lime | 1.6 |
| | 100.0 |

M. Robin gives the depth of the beds as varying from five to twenty-one yards: the coal is a perfect black, has a slight metallic lustre, and its fracture is conchoidal, when made in the mass.—Its density is very great, and by reason of its great compactness, it kindles with difficulty, and consumes slowly.

The same properties are observable in the analysis of the Welsh, and also of the American anthracites, all of which exhibit peculiar features, as to their density, and their resistance to combustion.

These coals will pass through a smelting furnace, exposed to intense heat, for a period of 48 hours, with no other apparent change than their surfaces being slightly calcined. When these specimens are broken, the interior fractures exhibit the same black lustre as is observable in the raw material.

Out of three specimens of American anthracite coal, analyzed by Professor Johnson, the following products were obtained—

| | | |
|---|---|---|
| "Specimen No. 1, when heated to a temperature sufficient to expel the water which it contains, without decomposition, lost per cent | | 1.915 |
| When the dried coal is ignited to redness for some time in a close vessel, it yields carbonic oxide, and carburetted hydrogen with a small portion of sulphur | | 5.068 |
| The remaining fixed carbon is | | 88.187 |
| Earthy matter 4.83 per cent., viz., | Silica | 2.589 |
| | Alumina | 1.772 |
| | Peroxide of iron | .270 |
| | Lime | .138 |
| | Magnesia | .052 |
| | Protoxide of Manganese | .009 |
| | | 100.000 |

From the latter numbers it will be perceived, that of the fixed ingredients or ashes of this coal, 100 parts will be composed—

| | |
|---|---|
| Of Silica | 53.604 |
| " Alumina | 36.687 |
| " Peroxide of iron | 5.590 |
| " Lime | 2.857 |
| " Magnesia | 1.076 |
| " Protoxide of Manganese | .186 |
| | 100.000 |

The ashes of this coal are of a yellowish white, or very light buff colour, and very bulky."

In speaking of No. 1, specimen, Mr. Johnson describes it as a compact structure, giving conchoidal fractures in all directions, apparently indifferent to the surface of deposition, which are manifested only by alternating lines or seams of bluish black, and jet black, which mark the successive layers. He states the appearance to give the idea, that the surfaces have been in a great measure obliterated, while the whole mass was, from some cause, in a semi-fluid state. The specific gravity is stated at 1.591 or 99½ lbs. to the cubic foot.

No. 2, specimen, experimented upon by Professor Johnson, gave a specific gravity of 1.574, or 98⅓ lbs. to the cubic foot, and yielded 85.909 per cent. of carbon.

No. 3, specimen, was found to have a specific gravity of 1.55 or 96¾ lbs to the cubic foot; and carbon, not volatile at a white heat, equal to 90.705 per cent.

The above analysis not only shows the composition of this description of fuel, but exhibits the density and compactness of its structure. It also affords evidence of its fitness for the smelting

furnace, and its adaptation to purposes where a great heating power is required. This description of coal, although well known for many years to the miners and iron manufacturers of South Wales, has, nevertheless, been much neglected, and its valuable, as well as economical properties almost entirely overlooked by them, from the circumstance of their inability to burn it.

Mr. Martin, in 1804, made the first attempt to use anthracite for the fusion of iron ore, but without any satisfactory results; twenty years afterwards, other trials were made to form a conglomerate coke, composed of anthracite and bituminous coal, but these, like the former, were unsuccessful. Mr. Crane, of the Yniscedwyn iron works, was the first to introduce, exclusively, anthracite for the purpose of smelting; first by its introduction to the cupola, and subsequently to the smelting furnace, by the use of the hot blast. Mr. Price of Neath Abbey, also made several experiments on this mineral, and found that about 8 cwt. of bituminous coal, coked in ovens, mixed with 25 cwt. of anthracite, gave one ton of iron; effecting a saving greater than anything yet accomplished by the hot blast, and the common coal.

The Ystalyfera ores are reduced in the same manner as those at Yniscedwyn, chiefly or entirely by anthracite coal in the raw state. The process is as nearly as possible, the same as that used at coke furnaces, the charge being, coal, 5 cwt., and mine (according to the working of the furnace, and the quality of iron to be produced), from 6 to 8 cwt—the average proportion of limestone as flux—being nearly one-third of the quantity of mine used.

Mr. Thomas Bevan, of the Ystalyfera works, in handing me specimens of the iron ore, stated that he attaches no importance to the specific gravity of the minerals. Some of the ores have, however, been analyzed, three of which are as follows—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| No. 1, | Specific | Gravity, | 3.358, | yielding | iron | 28.70 | per cent. |
| 2, | „ | „ | 3.417, | „ | „ | 20.35 | „ |
| 3, | „ | „ | 3.521, | „ | „ | 38.50 | „ |

From the above it will be seen that although the specific gravity of all the specimens is nearly alike, yet the degree of richness varies considerably; No. 3 specimen yielding nearly double the quantity of iron to No. 2.

The analysis of the specimens sent by Mr. Bevan, is as annexed.

| | No. 1. Rhonson. | No. 2. Pin Melin. |
|---|---|---|
| Silicate of alumina | 31.60 | 20.60 |
| Alumina | .50 | |
| Lime | 1.70 | .10 |
| Magnesia | 2.55 | .25 |
| Iron | 25.10 | 34.95 |
| Manganese | 1.19 | .80 |
| Sulphur | .55 | |
| Carbonic acid and water | 28.65 | 32.65 |
| Oxygen with iron | 7.20 | 9.95 |
| Ditto with manganese | .68 | .46 |
| Total found | 99.72 | 99.76 |
| Loss | .28 | .24 |
| | 100.00 | 100.00 |

Having ascertained the constituents of the anthracite formations, and their fitness for the smelting furnace, it now becomes necessary to direct attention to the properties of the iron made from this fuel. On a former occasion forty-nine different sorts of the British irons were experimented upon; they were carefully tested, and the results (accompanied with considerable detail) have since been printed in the society's Memoirs. The anthracite irons have undergone a similar treatment; and the experiments having been conducted under the immediate superintendence of my friend, Mr. Hodgkinson, I have no hesitation in vouching for the accuracy with which they were made.

The bars having been cast as before, 1 inch square, were placed on supports 4 feet 6 inches asunder; and by the usual method of suspending weights from the middle, the strengths, deflections, elasticities, &c. were obtained, as follows—

No. 1.

## WELSH IRONS.

Yniscedwyn Anthracite, No. 1, Pig Iron, Hot Blast.

| *Experiment 1st.*<br>Depth of bar ...... 1.017<br>Breadth of do. ...... 1.014<br>Distance between supports ...... 4ft. 6in.<br>Weight of bar 5 feet long, 15lbs. 6oz. | | | *Experiment 2nd.*<br>Depth of bar ...... 1.026<br>Breadth of do. ...... 1.010<br>Distance between supports ...... 4ft. 6 in.<br>Weight of bar 5 feet long, 15lbs. 6½oz. | | | *Experiment 3rd.*<br>Depth of bar ...... 1.023<br>Breadth of do. ...... 1.015<br>Distance between supports ...... 4ft. 6in.<br>Weight of bar 5 feet long 15lbs. 10oz. | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .077 | .005 | 28 | .075 | + | 28 | .065 | + |
| 56 | .150 | .013 | 56 | .150 | .015 | 56 | .142 | + |
| 112 | .330 | .022 | 112 | .301 | .021 | 112 | .290 | .011 |
| 224 | .656 | .070 | 224 | .649 | .066 | 224 | .645 | .055 |
| 336 | 1.065 | .135 | 336 | 1.043 | .130 | 336 | 1.053 | .122 |
| 392 | 1.320 | | 448 | 1.516 | .250 | 448 | 1.550 | .245 |
| 448 | 1.568 | .255 | 483 | broke | | 483 | 1.720 | |
| 459 | broke | | | | | 490 | 1.760 | broke |
| ∴ Ultimate deflection, =1.616. | | | ∴ Ultimate deflection, 1.664. | | | ∴ Ultimate deflection, = 1.800. | | |

Results reduced to those of Bars 1. 00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight (*b.*) | Ultimate deflection (*d.*) | Product, $b \times d$ or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports...... | 7.086 | | 437.66 | 1.643 | 719.1 |
| Experiment 2nd, bar 4ft. 6in. between supports...... | 7.118 | 13,459,200 | 454.29 | 1.707 | 775.5 |
| Experiment 3rd, bar 4ft. 6in. between supports...... | 7.029 | 14,023,600 | 467.89 | 1.841 | 861.4 |
| Mean.................................. | 7.078 | | 453.28 | 1.730 | 785.3 |

The Anthracite No. 1 Iron, when examined by the microscope, exhibits nearly the same appearance in the fracture as the Bute specimen, in No. XI. Table of my former experiments. It is rather fine-grained for a No. 1, Iron, porous in the centre, and slightly tinged with a grayish blue colour. Judging from the experiments, I should consider this a useful iron, as it works freely, and possesses considerable powers to resist a transverse strain.

## No. II.

## WELSH IRONS.

### Yniscedwyn Anthracite, No. 1, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar ....... 1.027 Breadth of do....... 1.006 Distance between supports........2ft. 3in. | | | *Experiment 2nd.* Depth of bar ...... 1.017 Breadth of do....... 1.009 Distance between supports........2ft. 3in. | | | *Experiment 3rd.* Depth of bar ...... 1.025 Breadth of do. ...... 1.011 Distance between supports........ 2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 112 | .025 | | 112 | .040 | | 112 | .040 | |
| 224 | .060 | | 224 | .081 | | 224 | .080 | |
| 336 | .105 | | 336 | .125 | | 336 | .122 | |
| 448 | .152 | | 448 | .167 | | 448 | .164 | |
| 560 | .202 | | 560 | .205 | | 560 | .207 | |
| 672 | .250 | | 672 | .250 | | 672 | .250 | |
| 784 | .315 | | 784 | .300 | | 784 | .310 | |
| 896 | .390 | | 896 | .375 | | 896 | .365 | |
| | | | 952 | .410 | | 952 | broke | |
| | | | 980 | .440 | | | | |
| | | | 1008 | .455 | | | | |
| | | | 1036 | broke | | | | |
| Broke with laying the weight, 896lbs., on again. | | | ∴ Ultimate deflection, =.470. | | | ∴ Ultimate deflection, =.393. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight ($b.$) | Ultimate deflection ($d.$) | Product $b \times d$, or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 2ft. 3in. between supports....... | | | 897.2 | .440 | 394.8 |
| Experiment 2nd, bar 2ft. 3in. between supports....... | | | 992.7 | .478 | 474.2 |
| Experiment 3rd, bar 2ft. 3in. between supports....... | | | 892.1 | .403 | 359.5 |
| Mean.............................. | | | 927.3 | .440 | 409.5 |

## No. III.
## WELSH IRONS.
### Yniscedwyn Anthracite, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st.*<br>Depth of bar........ 1.031<br>Breadth of do ...... 1.014<br>Distance between supports ........4ft 6in<br>Weight of bar 5 feet long, 15lbs 13oz | | | *Experiment 2nd.*<br>Depth of bar ...... 1.025<br>Breadth of do ...... 1.026<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 12oz | | | *Experiment 3rd.*<br>Depth of bar........ 1.015<br>Breadth of do ...... 1.023<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 10oz | | | *Experiment 4th.*<br>Depth of bar........ 1.027<br>Breadth of do ...... 1.016<br>Distance between supports ........ 2ft 3in | | | *Experiment 5th.*<br>Depth of bar........ 1.025<br>Breadth of do....... 1.025<br>Distance between supports ........2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 28 | .065 | | 28 | .062 | | 28 | .066 | | 224 | .065 | | 112 | .038 | |
| 56 | .132 | + | 56 | .130 | + | 56 | .134 | + | 336 | .090 | | 224 | .076 | |
| 112 | .254 | .011 | 112 | .263 | .013 | 112 | .271 | .015 | 448 | .130 | | 336 | .110 | |
| 224 | .540 | .040 | 224 | .560 | .033 | 224 | .575 | .043 | 560 | .165 | | 448 | .141 | |
| 336 | .862 | .074 | 336 | .867 | .071 | 336 | .900 | .075 | 672 | .210 | | 560 | .190 | |
| 448 | 1.220 | .140 | 448 | 1.230 | .131 | 448 | 1.272 | .145 | 784 | .260 | | 672 | .224 | |
| 476 | 1.310 | | 504 | 1.422 | | 476 | 1.365 | | 896 | .308 | | 784 | .265 | |
| 504 | 1.415 | .185 | 522 | broke | | 504 | 1.485 | .188 | 1008 | .345 | | 896 | .308 | |
| | | | | | | 529 | broke | | 1064 | .384 | | 1008 | .355 | |
| | | | | | | | | | 1120 | .410 | | 1106 | broke | |
| | | | | | | | | | 1176 | .440 | | | | |
| | | | | | | | | | 1180 | broke | | | | |
| Broke, with laying the weight, 504lbs, on again; great care was used. | | | ∴ Ultimate deflection =1.484. | | | ∴ Ultimate deflection =1.593. | | | ∴ Ultimate deflection =.442. | | | ∴ Ultimate deflection =.396. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports ... | 7.088 | 15,620,400 | 467.6 | 1.449 | 677.50 |
| Experiment 2nd, bar 4ft. 6in. between supports ... | 7.118 | 15,172,750 | 484.26 | 1.521 | 636.56 |
| Experiment 3rd, bar 4ft. 6in. between supports ... | 7.079 | 15,208,850 | 501.9 | 1.617 | 811.57 |
| Mean.................................. | 7.095 | 15,334,000 | 484.6 | 1.529 | 708.54 |
| Experiment 4th, bar 2ft. 3in. between supports ... | | | 1101.1 | .498 | 548.35 |
| Experiment 5th, bar 2ft. 3in. between supports ... | | | 1027.0 | .406 | 416.96 |
| Mean.................................. | | | 1064.0 | .452 | 482.65 |

No. 2, is similar in colour to No. 1, Iron, but closer-grained, and accompanied with the usual appearance of compact crystals round the edges of the fracture. It is a free-working Iron, and ranks well in the scale of strengths.

## No. IV.
## WELSH IRONS.
### Yniscedwyn Anthracite, No, 3, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar........ 1.010 Breadth of do....... 1.008 Distance between supports........4ft. 6in. Weight of bar 5 feet long, 15lbs. 7oz. | | | *Experiment 2nd.* Depth of bar........ 1.018 Breadth of do....... 1.010 Distance between supports........4ft. 6in. Weight of bar 5 feet long, 15lbs. 9oz. | | | *Experiment 3rd.* Depth of bar........ 1.024 Breadth of do....... 1.012 Distance between supports........4ft. 6in, Weight of bar 5 feet long, 15lbs. 11oz. | | | *Experiment 4th,* Depth of bar........ 1.012 Breadth of do....... 1.015 Distance between supports........2ft. 3in. | | | *Experiment 5th.* Depth of bar........ 1.025 Breadth of do....... 1.006 Distance between supports........2ft. 3in. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 28 | .065 | + | 28 | .064 | + | 28 | .060 | | 112 | .035 | | 112 | .020 | |
| 56 | .132 | .010 | 56 | .125 | + | 56 | .120 | + | 224 | .070 | | 224 | .055 | |
| 112 | .263 | .014 | 112 | .255 | .010 | 112 | .252 | .006 | 336 | .105 | | 336 | .090 | |
| 224 | .555 | .032 | 224 | .545 | .031 | 224 | .533 | .024 | 448 | .140 | | 448 | .125 | |
| 336 | .875 | .070 | 336 | .850 | .065 | 336 | .838 | .055 | 560 | .175 | | 560 | .155 | |
| 448 | 1.225 | .115 | 448 | 1.190 | .110 | 448 | 1.175 | .108 | 672 | .215 | | 672 | .185 | |
| 504 | 1.420 | .155 | 504 | 1.375 | .145 | 504 | 1.360 | .138 | 784 | .250 | | 784 | .232 | |
| 529 | broke | | 553 | broke | | 532 | broke | | 896 | .295 | | 896 | .271 | |
| | | | | | | | | | 1008 | .340 | | 1008 | .323 | |
| | | | | | | | | | 1064 | .365 | | 1092 | .344 | |
| | | | | | | | | | 1078 | broke | | 1120 | .360 | |
| | | | | | | | | | | | | 1124 | broke | |
| ∴ Ultimate deflection =1.507. | | | ∴ Ultimate deflection =1.537. | | | ∴ Ultimate deflection =1.453. | | | ∴ Ultimate deflection =.371. | | | ∴ Ultimate deflection =.362. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \frac{1}{2} d$, or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports...... | 7.206 | 16,179,650 | 514.5 | 1.522 | 783.1 |
| Experiment 2nd, bar 4ft. 6in. between supports ... | 7.114 | 16,264,630 | 528.3 | 1.565 | 826.8 |
| Experiment 3rd, bar 4ft. 6in. between supports ... | 7.184 | 16,138,700 | 501.3 | 1.488 | 745.9 |
| Mean.................................... | 7.168 | 16,194,327 | 514.7 | 1.525 | 785.3 |
| Experiment 4th, bar 2ft. 3in. between supports ... | | | 1037.1 | .375 | 388.9 |
| Experiment 5th, bar 2ft. 3in. between supports ... | | | 1063.5 | .372 | 395.6 |
| Mean.................................... | | | 1050.3 | .373 | 392.2 |

This is a rigid strong Iron, finely granulated, and presents an appearance of great uniformity in the fracture. Colour a whitish gray. It is exceedingly dense, of high specific gravity, but not particularly hard, as it yields with comparative ease to the chisel and file.

## No. V.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 1, Pig Iron, Hot Blast.

| *Experiment 1st.*<br>Depth of bar........ 1.035<br>Breadth of do ...... 1.050<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 14oz | | | *Experiment 2nd.*<br>Depth of bar........ 1.035<br>Breadth of do ...... 1.053<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 15oz | | | *Experiment 3rd.*<br>Depth of bar ...... 1.027<br>Breadth of do ...... 1.048<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 11oz | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 28 | .075 | | 28 | .073 | + | 28 | .075 | + |
| 56 | .152 | + | 56 | .152 | .012 | 56 | .155 | .012 |
| 112 | .320 | .024 | 112 | .333 | .040 | 112 | .338 | .032 |
| 224 | .728 | .090 | 224 | .730 | .113 | 224 | .760 | .095 |
| 336 | 1.240 | .205 | 336 | 1.250 | .210 | 336 | 1.285 | .216 |
| 392 | 1.550 | .300 | 448 | 1.922 | .453 | 392 | 1.610 | |
| 448 | 1.910 | .442 | 476 | broke | | 448 | 2.000 | .480 |
| 476 | 2.105 | | | | | 473 | broke | |
| 501 | broke | | | | | | | |
| ∴ Ultimate deflection, =2.279. | | | ∴ Ultimate deflection, =2.090. | | | ∴ Ultimate deflection, =2.174. | | |

| Results reduced to those of Bars 1.00 inch square. | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports ... | 7.000 | 11,835,300 | 445.4 | 2.359 | 1050.7 |
| Experiment 2nd, bar 4ft. 6in. between supports ... | 6.974 | 11,340,806 | 421.9 | 2.163 | 912.6 |
| Experiment 3rd, bar 4ft. 6in. between supports ... | 7.007 | 11,490,800 | 427.9 | 2.233 | 955.5 |
| Mean.................................... | 6.992 | 11,555,635 | 434.7 | 2.252 | 972.9 |

The Ystalyfera No. 1 Iron (first sample) is rather weaker than the Yniscedwyn of the same class; it is, however, very ductile, and possesses great power of resisting impact. In this respect it is the best Iron I have yet experimented upon, the mean ultimate deflection from three experiments being 2.252. The deflection of this Iron is greater than that of any other recorded in my former experiments. It has considerable elastic power, and bends through a large space before it breaks. Colour a bluish gray.

## No. VI.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 1, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar........ 1.025; Breadth of do ...... 1.038; Distance between supports ........ 2ft 3in | | | *Experiment 2nd.* Depth of bar........ 1.016; Breadth of do ...... 1.037; Distance between supports..........2ft 3in | | | *Experiment 3rd.* Depth of bar........ 1.030; Breadth of do ...... 1.037; Distance between supports ........ 2ft 3in | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 112 | .045 | | 112 | .045 | | 112 | .046 | |
| 224 | .090 | | 224 | .093 | | 224 | .097 | |
| 336 | .130 | | 336 | .140 | | 336 | .149 | |
| 448 | .180 | | 448 | .200 | | 448 | .205 | |
| 560 | .225 | | 560 | .270 | | 560 | .271 | |
| 672 | .285 | | 672 | .335 | | 672 | .345 | |
| 784 | .353 | | 784 | .420 | | 784 | .438 | |
| 896 | .450 | | 896 | broke | | 840 | .495 | |
| 938 | broke | | | | | 868 | .516 | |
| | | | | | | 896 | .545 | |
| | | | | | | 910 | .561 | |
| | | | | | | 924 | broke | |
| ∴ Ultimate deflection, =.486. | | | ∴ Ultimate deflection, =.505. | | | | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
|---|---|---|---|---|---|
| Experiment 1st, bar 2ft. 3in. between supports...... | | | 860.1 | .498 | 428.3 |
| Experiment 2nd, bar 2ft. 3in. between supports ... | | | 837.0 | .513 | 429.4 |
| Experiment 3rd, bar 2ft. 3in. between supports ... | | | 839.9 | .594 | 498.9 |
| Mean.................................... | | | 845.7 | .535 | 452.2 |

## No. VII.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st.*<br>Depth of bar ...... 1.040<br>Breadth of do. ...... 1.026<br>Distance between supports ...... 4ft. 6in.<br>Weight of bar 5 feet long, 15lbs 12oz | | | *Experiment 2nd.*<br>Depth of bar ...... 1.022<br>Breadth of do. ...... 1.046<br>Distance between supports........ 4ft 6 in<br>Weight of bar 5 feet long, 15lbs 10oz | | | *Experiment 3rd.*<br>Depth of bar ...... 1.018<br>Breadth of do. ....... 1.041<br>Distance between supports ........ 4ft 6in<br>Weight of bar 5 feet long, 15lbs 9oz | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. | Weight in lbs. | Deflection in inches. | Deflection load removed. |
| 28 | .062 | .005 | 28 | .065 | + | 28 | .065 | |
| 56 | .132 | .011 | 56 | .135 | + | 56 | .135 | .005 |
| 112 | .270 | .049 | 112 | .294 | .014 | 112 | .280 | .013 |
| 224 | .590 | .100 | 224 | .632 | .050 | 224 | .648 | .053 |
| 336 | .965 | .197 | 336 | 1.039 | .120 | 336 | 1.058 | .124 |
| 448 | 1.380 | .279 | 448 | 1.540 | .250 | 448 | 1.580 | .261 |
| 504 | 1.650 | | 473 | broke | | 476 | 1.732 | |
| 522 | broke | | | | | 490 | broke | |
| ∴ Ultimate deflection, =1.742. | | | ∴ Ultimate deflection, =1.679. | | | ∴ Ultimate deflection, =1.804. | | |

Results reduced to those of Bars 1.00 inch square.

| | Specific gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports...... | 7.043 | 14,149,705 | 470.4 | 1.812 | 852.4 |
| Experiment 2nd, bar 4ft. 6in. between supports ... | 7.022 | 13,432,200 | 432.9 | 1.716 | 742.9 |
| Experiment 3rd, bar 4ft. 6in. between supports ... | 7.093 | 14,337,906 | 454.2 | 1.836 | 833.9 |
| Mean.................................... | 7.053 | 13,973,270 | 452.5 | 1.788 | 809.7 |

Ystalyfera No. 2 Iron (first sample.)—Appearance of the fracture, a dark gray, with the crystals more minute, and in closer contact than in No. 1 specimen. It is rather a soft Iron, easily cut with the chisel or file, and is well adapted for mixing with Irons of greater tenacity.

## No. VIII.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 2, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar ....... 1.018; Breadth of do....... 1.031; Distance between supports ........2ft 3in | | | *Experiment 2nd.* Depth of bar ...... 1.022; Breadth of do....... 1.020; Distance between supports ........2ft 3in | | | *Experiment 3rd.* Depth of bar ...... 1.008; Breadth of do. ...... 1.024; Distance between supports ........ 2ft 3in | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection load removed | Weight in lbs | Deflection in inches | Deflection load removed | Weight in lbs | Deflection in inches | Deflection load removed |
| 112 | .032 | | 112 | .035 | | 112 | .450 | |
| 224 | .075 | | 224 | .075 | | 224 | .850 | |
| 336 | .113 | | 336 | .123 | | 336 | .132 | |
| 448 | .160 | | 448 | .165 | | 448 | .166 | |
| 560 | .210 | | 560 | .211 | | 560 | .212 | |
| 672 | .259 | | 672 | .255 | | 672 | .262 | |
| 784 | .322 | | 784 | .312 | | 784 | .315 | |
| 896 | broke | | 896 | .375 | | 896 | .385 | |
| | | | 1008 | .455 | | 952 | .424 | |
| | | | 1012 | broke in 5 min. | | 973 | broke | |
| ∴ Ultimate deflection, =.385 | | | ∴ Ultimate deflection, =.458. | | | ∴ Ultimate deflection, =.439. | | |

| Results reduced to those of Bars 1.00 inch square. | | | | | |
|---|---|---|---|---|---|
| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
| Experiment 1st, bar 2ft. 3in between supports ... | | | 838.6 | .392 | 328.7 |
| Experiment 2nd, bar 2ft. 3in. between supports ... | | | 949.9 | .468 | 444.6 |
| Experiment 3rd, bar 2ft, 3in. between supports ... | | | 935.2 | .443 | 414.3 |
| Mean.................................... | | | 907.9 | .434 | 395.9 |

## No. IX.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 3, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar........ 1.040 Breadth of do ...... 1.023 Distance between supports ........ 4ft 6in Weight of bar 5 feet long, 15lbs 12oz | | | *Experiment 2nd.* Depth of bar........ 1.005 Breadth of do ...... 1.060 Distance between supports ........ 4ft 6in Weight of bar 5 feet long, 15lbs 13oz | | | *Experiment 3rd.* Depth of bar ...... 1.015 Breadth of do ...... 1.040 Distance between supports ........ 4ft 6in Weight of bar 5 feet long, 15lbs 9oz | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 28 | .064 | | 28 | .070 | + | 28 | .064 | |
| 56 | .133 | .005 | 56 | .145 | .006 | 56 | .136 | .005 |
| 112 | .283 | .013 | 112 | .304 | .015 | 112 | .305 | .016 |
| 224 | .628 | .045 | 224 | .665 | .044 | 224 | .682 | .058 |
| 336 | 1.000 | .102 | 336 | 1.095 | .105 | 336 | 1.100 | .115 |
| 448 | 1.450 | .195 | 448 | 1.600 | .222 | 448 | 1.600 | .230 |
| 476 | 1.570 | broke | 504 | 1.885 | .315 | 490 | 1.828 | |
| | | | | | | 504 | 1.920 | broke |
| Broke whilst taking deflection. | | | Broke one inch from the centre, with laying on the weight again. | | | Broke whilst taking deflection. | | |

Results reduced to those of Bars 1. 00 inch square.

| | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight ($b$) | Ultimate deflection ($d$) | Product, $b \times d$ or power of resisting impact |
|---|---|---|---|---|---|
| Experiment 1st, bar 4ft. 6in. between supports...... | 7.126 | 13,538,710 | 430.2 | 1.633 | 702.5 |
| Experiment 2nd, bar 4ft. 6in. between supports,..... | 7.143 | 13,479,205 | 470.8 | 1.894 | 891.7 |
| Experiment 3rd, bar 4ft. 6in. between supports...... | 7.129 | 13,292,505 | 470.4 | 1.950 | 917.3 |
| Mean.................................. | 7.133 | 13,436,806 | 457.1 | 1.825 | 837.2 |

Ystalyfera, No. 3, is a dense and closely granulated Iron. Like most other No. 3 Irons, it exhibits great uniformity in its crystaline formation, accompanied with a slight degree of porosity in the centre of the fracture. This is, however, common to every description of Cast Iron, and varies according to the size of the casting. Colour, a whitish gray.

## No. X.

## WELSH IRONS.

### Ystalyfera Anthracite, No. 3, Pig Iron, Hot Blast.

| *Experiment 1st.* Depth of bar ........ 1.016 Breadth of do ...... 1.035 Distance between supports ........2ft 3in | | | *Experiment 2nd.* Depth of bar ...... 1.050 Breadth of do ...... 1.005 Distance between supports ........ 2ft 3in | | | *Experiment 3rd.* Depth of bar ........ 1.015 Breadth of do. ...... 1.040 Distance between supports ........ 2ft 3in | | |
|---|---|---|---|---|---|---|---|---|
| Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed | Weight in lbs | Deflection in inches | Deflection, load removed |
| 112 | .030 | | 112 | .035 | | 112 | .037 | |
| 224 | .075 | | 224 | .074 | | 224 | .078 | |
| 336 | .122 | | 336 | .114 | | 336 | .128 | |
| 448 | .170 | | 448 | .160 | | 448 | .175 | |
| 560 | .216 | | 560 | .197 | | 560 | .220 | |
| 672 | .260 | | 672 | .244 | | 672 | .266 | |
| 784 | .310 | | 784 | .298 | | 784 | .323 | |
| 896 | .370 | | 896 | .354 | | 896 | .385 | |
| 1008 | .436 | | 1008 | .420 | | 945 | broke | |
| 1064 | .481 | | 1036 | broke | | | | |
| 1092 | .498 | | | | | | | |
| 1106 | broke | | | | | | | |
| ∴ Ultimate deflection =.507. | | | ∴ Ultimate deflection =.435. | | | ∴ Ultimate deflection =.434. | | |

| Results reduced to those of Bars 1.00 inch square. | Specific Gravity. | Modulus of elasticity in lbs. per square inch. | Breaking weight ($b$.) | Ultimate deflection ($d$.) | Product $b \times d$, or power of resisting impact. |
|---|---|---|---|---|---|
| Experiment 1st, bar 2ft. 3in. between supports...... | | | 1035.2 | .515 | 533.1 |
| Experiment 2nd, bar 2ft. 3in. between supports...... | | | 935.0 | .457 | 427.3 |
| Experiment 3rd, bar 2ft. 3in. between supports...... | | | 882.0 | .441 | 389.0 |
| Mean.................................... | | | 950.7 | .471 | 449.8 |

After the preceding experiments were made, Mr. Richard Evans forwarded from the proprietors of the Ystalyfera iron works, other samples of the iron, Nos. 1, 2, and 3, which, I was informed, were made with anthracite coal alone, whilst the first samples were smelted with anthracite, mixed with a small portion of bituminous coke. In both cases a blast of heated air was used. Feeling desirous of ascertaining the comparative strength of the iron in the two cases, I cheerfully acceded to the wishes of the proprietors, and had experiments made upon the second sample, precisely similar to those made on the first.

## No. XI.

## RESULTS OF EXPERIMENTS

UPON THE SECOND SAMPLE OF YSTALYFERA CAST IRON, MADE WITH ANTHRACITE COAL.

The results are from bars 4ft. 6in. between the supports, and one inch square exactly.

| | | Specific Gravity | Modulus of elasticity in lbs | Breaking weight ($b$) | Ultimate deflection ($d$) | Product $b \times d$, or power of resisting impact |
|---|---|---|---|---|---|---|
| No. 1, Iron. | Experiment 1st | 6.917 | 14,076,600 | 378.3 | 1.385 | 523.9 |
| | ,, 2nd | 7.288 | 14,236,950 | 398.8 | 1.451 | 578.7 |
| | ,, 3rd | 7.112 | 14,017,180 | 370.4 | 1.330 | 492.6 |
| | ,, 4th | 7.075 | 13,846,950 | 421.7 | 1.614 | 679.6 |
| | Mean | 7.098 | 14,044,420 | 392.3 | 1.445 | 568.7 |
| No. 2, Iron. | Experiment 1st | 7.300 | 15,965,800 | 521.2 | 1.733 | 903.2 |
| | ,, 2nd | 7.347 | 15,928,700 | 491.7 | 1.502 | 738.5 |
| | ,, 3rd | 7.328 | 15,740,100 | 434.4 | 1.283 | 557.3 |
| | ,, 4th | 7.059 | 15,112,400 | 475.4 | 1.503 | 714.5 |
| | Mean | 7.258 | 15,686,750 | 480.7 | 1.505 | 728.4 |
| No. 3, Iron. | Experiment 1st | 7.292 | 18,878,000 | 491.7 | 1.304 | 641.2 |
| | ,, 2nd | 7.256 | 17,826,250 | 525.2 | 1.421 | 746.3 |
| | ,, 3rd | 7.180 | 17,998,400 | 494.3 | 1.275 | 630.2 |
| | ,, 4th | 7.381 | 18,863,050 | 496.4 | 1.297 | 643.8 |
| | Mean | 7.352 | 18,391,425 | 501.9 | 1.324 | 665.4 |

### REMARKS ON THE PRECEDING IRONS.

No. 1 has nearly the same appearance as to colour and porosity in the centre of the fracture, as No. 1, of the first sample: it is a soft, fluid iron, and apparently well adapted for the lighter descriptions of castings.

No. 2 is of greater density than the corresponding number in the first sample; it indicates a strong, compact structure, accompanied with the usual appearance of minute crystals on the outer edges of the fracture. Colour a whitish gray.

No. 3 is rather more compact in its crystalline structure than the No. 3 of the first sample. The fracture presents a greater admixture of white than that of No. 2, and when viewed by the microscope, immediately after fracture, the crystals emit a clear brilliant light.

At the conclusion of my former paper in this volume, I gave a general summary of results comprising the strength and other properties of forty-nine sorts of British irons. They were ranked according to their relative strengths, taken from the mean breaking weights of bars one inch square, placed upon supports 4ft. 6in. asunder. The strongest being marked No. 1, and the others according to their respective ranks in the scale.*

On this occasion it will be necessary to follow the same rule as that formerly used, and to collect the results from the experiments on the anthracite iron, into a similar form.

I have found these summaries of considerable value in judging of the different kinds of iron; and if they were generally used, and taken as a guide by the architect and engineer, I have every reason to hope that improper mixtures, as well as the use of improper material in castings, would be prevented.

* The irons experimented upon were mostly obtained from the makers or their agents; and if any iron should be misrepresented, or not have had full justice done to it, it will afford me great pleasure to rectify the defect or omission.

# SUMMARY OF RESULTS

## OBTAINED FROM THE PRECEDING EXPERIMENTS ON RECTANGULAR BARS OF ANTHRACITE CAST IRON, EACH BAR BEING REDUCED TO EXACTLY ONE INCH SQUARE.

In the following abstract, the transverse strength, which may be taken as the chief criterion of the value of each Iron, is obtained from the mean of the experiments; first, on long bars, 4ft. 6in. between supports, and next, on those of half the length, or 2ft. 3in. between supports.

All the other values are deduced from the 4ft. 6in. bars.

| No. of Iron in the scale of strength | Names of Irons. | Number of experiments on each | Specific Gravity | Modulus of elasticity in lbs per square inch | Breaking weight in lbs of bars 4ft 6in between supports | Breaking weight in lbs of bars 2ft 3in, reduced to 4ft 6in between supports | Mean breaking weight in lbs (S) | | Ultimate deflection of 4ft 6in bars, in parts of an inch | Power of the 4ft 6in bars to resist impact | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Yniscedwyn, No. 3............... | 5 | 7.168 | 16,194,327 | 515 | 525 | 520 | | 1.525 | 785 | |
| 2 | ,, ,, 2............... | 5 | 7.095 | 15,334,000 | 485 | 532 | 508 | | 1.529 | 709 | |
| 3 | Ystalyfera ,, 3, 2nd do | 4 | 7.352 | 18,391,425 | 502 | | 502 | mean 472 | 1.324 | 665 | mean 751 |
| 4 | ,, ,, 3, 1st do | 6 | 7.133 | 13,436,806 | 457 | 425 | 441 | | 1.825 | 837 | |
| 5 | ,, ,, 2, 2nd do | 4 | 7.258 | 15,686,750 | 481 | | 481 | mean 468 | 1.505 | 728 | mean 769 |
| 6 | ,, ,, 2, 1st do | 6 | 7.053 | 13,973,270 | 453 | 454 | 454 | | 1.788 | 810 | |
| 7 | Yniscedwyn ,, 1............... | 6 | 7.078 | 13,741,400 | 453 | 464 | 458 | | 1.730 | 785 | |
| 8 | Ystalyfera ,, 1, 1st sample | 6 | 6.992 | 11,555,635 | 435 | 423 | 429 | mean 410 | 2.252 | 973 | mean 771 |
| 9 | ,, ,, 1, 2nd do | 4 | 7.098 | 14,044,420 | 392 | | 392 | | 1.445 | 569 | |

In estimating the value of any particular iron, it must be remembered, that its resistance, or rigidity under strain, is exclusively the criterion of its strength, but not the measure of its utility. Some irons of the very first quality exhibit weakness under strain, but possess, at the same time, great richness and fluidity, accompanied with elastic powers of no ordinary description. For example, the Ystalyfera No. 1, first sample, is an iron of this character, and although inferior to other irons, as respects strength, it has, nevertheless, great flexure, the ultimate deflection being 2.252, which is greater than that of any other iron I have yet experimented upon. In its powers to resist impact, it approaches nearly to the Gartsherrie, Ponkey, and Elsicar irons, the numbers being—

| | | |
|---|---|---|
| Gartsherrie | No. 3=998 | Powers to resist impact. |
| Ponkey | No. 3=992 | |
| Elsicar | No. 2=992 | |
| Ystalyfera | No. 1=973 | |

No. 1 of the Ystalyfera second sample, is inferior, both as regards strength, and its powers of resisting impact.

On comparing the results in the last table with those in the List of the General Summary,

at the conclusion of my former paper, we find that the iron from the Yniscedwyn works has considerable strength. No. 1 stands as No. 14 in the general summary, and has only two irons of the same number before it. No. 2 stands No. 6 in the list, and is stronger than any other iron of the same number. No. 3 stands No. 5 in the list, having only four others in advance of it.

On the whole, the Ystalyfera iron has less strength than the Yniscedwyn, but the first sample of it possessed toughness in a high degree; it was very flexible, and resisted impact with great tenacity. The second sample was stronger than the first, but offered less resistance to a blow. The mean results from the first and second samples of this iron, give 410, 468, and 472, for the strengths of Nos. 1, 2, and 3 respectively, the first of these standing as No. 45, the second as No. 12, and the third as No. 11, in the General Summary.

It may not be improper to mention, that the parties connected with the Ystalyfera iron works, have had other experiments made upon their own account; the strengths, as given by these

experiments, are greater than those obtained from either of the samples which I have received. I am unable to assign the cause of the difference which exists, and can only observe, that the preceding experiments were conducted with the greatest care, and the utmost attention was paid to every circumstance, however minute, in order to obtain correct results.

In conclusion, I would observe, that—judging from the experiments—I consider the use of anthracite coal rather favourable than otherwise to the manufacture of iron; and provided some well conducted experiments were made to ascertain the requisite proportions of flux and ore to this description of coal, much might be done to improve the quality of the iron, and to bring into useful operation a valuable and important mineral production.

# OBSERVATIONS

ON THE

# BAROMETER, THERMOMETER, & RAIN

## At Manchester,

## FROM THE YEAR 1794 TO 1840 INCLUSIVE,

BEING

## A SUMMARY OF ESSAYS ON METEOROLOGY.

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(Read at various times, from the year 1830 to 1840.)

At the close of the year 1818, I read an epitome of my meteorological observations for the preceding twenty-five years: these were afterwards printed in the third volume (new series) of the Society's Memoirs.* Such a lengthened series of observations could not fail to suggest inferences of a theoretical nature ; some of these

* In the essay above alluded to, I had occasion to refer to the transactions of the Royal Society of London for a series of observations of the like nature ; and, upon a comparison of those with my own, I found reason to believe that the Royal Society's observations and calculations from them, exhibited marks of carelessness which rendered them by no means trustworthy. I intimated the same in a note (see page 490 of the above-mentioned volume.) Some time after this,

were advanced and corroborated by the results of other Meteorologists. Since that time the period has been extended by the addition of twenty-two years more; and it is proposed in this communication to give a summary of the observations made in the last-mentioned period, and then to incorporate the results with those of the former period, so as to obtain averages for the entire of both periods.

If there is any natural tendency in the state of the atmosphere to produce rain (or any other phenomenon) more at one time of the year than another, it will be shewn by the observations of a few years. Ten or twelve successive years are almost certain to produce a good outline of the characteristic features of the year; but it may require half a century or more to obtain an exact delineation of them, and such as would render future observations of little or no avail in producing any sensible alteration. This observation is applicable to the fluctuations of the atmosphere

the Royal Society revised their Meteorological establishment, and placed it upon a most respectable footing, since which, I believe, they may vie with any public body, or private individual, in the regularity and accuracy of their observations and tabular results; and, I may add, that I have consulted them with pleasure and advantage since on several occasions.

in weight, as shewn by the Barometer, and to the temperature of the atmosphere, as well as the quantity of rain, and to the other meteoric phenomena.

## 1. Of the Barometer.

Experience proves that the weight or pressure of the atmosphere on the earth's surface is continually varying from winds and other causes; and there is reason to believe that *changes of weather* are in some way connected with these fluctuations in the weight of the atmosphere, and hence the utility of Barometrical Observations.

In the Torrid Zone the variation is little; in the Temperate Zone the variation is much greater; it increases with the latitude, and is about double in winter to what it is in summer, and it is probably still greater in the Frigid Zones.

Many people imagine that the variations are local—that the Barometers may rise in one town, and fall in another neighbouring town at the same time. This is not the case; the variations take place in London, Penzance, Dublin and Edinburgh, at the same time, and to the same amount nearly.

The results of my Barometrical observations are contained in the following table: the observations were made three times each day, namely, in the morning at eight o'clock, about one in the afternoon, and eleven in the evening. The monthly averages were found by adding all the observations together, and dividing the sum by the number of observations.

TABLE OF THE MEAN MONTHLY HEIGHTS AND ANNUAL HEIGHTS OF THE BAROMETER FOR TWENTY TWO YEARS, VIZ. FROM 1819 TO 1840 INCLUSIVE.

| Years. | Jany. In. | Feb. In. | Mar. In. | April In. | May. In. | June In. | July. In. | Aug. In. | Sept. In. | Oct. In. | Nov. In. | Dec. In. | An. Mns. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1819 | 29.78 | 29.70 | 30.00 | 29.90 | 30.02 | 29.98 | 30.10 | 30.13 | 30.05 | 29.93 | 29.83 | 29.79 | 29.93 |
| 1820 | 29.95 | 30.06 | 30.00 | 30.04 | 29.88 | 30.07 | 30.08 | 29.97 | 30.09 | 29.70 | 29.96 | 30.05 | 29.98 |
| 1821 | 29.99 | 30.33 | 29.70 | 29.76 | 29.99 | 30.21 | 30.03 | 30.06 | 29.93 | 29.98 | 29.83 | 29.49 | 29.94 |
| 1822 | 30.20 | 30.07 | 30.05 | 30.04 | 30.13 | 30.20 | 29.90 | 30.00 | 30.10 | 29.74 | 29.75 | 30.13 | 30.02 |
| 1823 | 29.83 | 29.52 | 29.89 | 29.93 | 29.99 | 30.03 | 29.90 | 29.96 | 30.07 | 29.83 | 30.19 | 29.70 | 29.90 |
| 1824 | 30.10 | 29.92 | 29.93 | 29.98 | 30.11 | 30.03 | 30.10 | 30.06 | 30.00 | 29.74 | 29.66 | 29.85 | 29.95 |
| 1825 | 30.26 | 30.19 | 30.14 | 30.04 | 29.98 | 30.08 | 30.14 | 30.02 | 29.98 | 30.02 | 29.76 | 29.64 | 30.02 |
| 1826 | 30.10 | 29.93 | 29.99 | 30.08 | 30.19 | 30.34 | 30.05 | 30.00 | 30.01 | 29.97 | 29.92 | 29.93 | 30.04 |
| 1827 | 29.91 | 30.14 | 29.71 | 30.05 | 29.85 | 29.99 | 30.12 | 30.09 | 30.07 | 29.85 | 30.07 | 29.80 | 29.97 |
| 1828 | 29.98 | 29.87 | 29.99 | 29.83 | 29.98 | 30.10 | 29.84 | 29.97 | 30.01 | 30.04 | 29.85 | 29.88 | 29.94 |
| 1829 | 29.85 | 30.04 | 29.88 | 29.52 | 30.06 | 30.00 | 29.78 | 29.87 | 29.77 | 29.99 | 30.00 | 30.11 | 29.90 |
| 1830 | 30.02 | 29.85 | 30.02 | 29 74 | 29.88 | 29.84 | 29.87 | 29.89 | 29.75 | 30.17 | 29.77 | 29.64 | 29.87 |
| 1831 | 29.87 | 29.81 | 29.85 | 29.76 | 29.97 | 29.96 | 29.96 | 29.98 | 29.92 | 29.79 | 29.82 | 29.73 | 29.87 |
| 1832 | 29.93 | 30.04 | 29.87 | 30.02 | 29.97 | 29.89 | 30.01 | 29.89 | 30.11 | 30.01 | 29.83 | 29.93 | 29.95 |
| 1833 | 30.17 | 29.37 | 29.91 | 29.77 | 30.11 | 29.78 | 30.03 | 29.57 | 29.92 | 29.81 | 29.86 | 29.63 | 29.82 |
| 1834 | 29.66 | 30.07 | 30.14 | 30.16 | 30.03 | 29.97 | 30.00 | 29.91 | 30.07 | 30.01 | 29.92 | 30.22 | 30.01 |
| 1835 | 30.02 | 29.69 | 29.89 | 30.11 | 29.88 | 30.08 | 30,09 | 29.98 | 29.70 | 29.77 | 29.90 | 30.12 | 29.93 |
| 1836 | 29.83 | 29.80 | 29.46 | 29.87 | 30.24 | 29.90 | 29.97 | 30.03 | 29.89 | 29.79 | 29.56 | 29.79 | 29.84 |
| 1837 | 29.84 | 30.04 | 29.94 | 30.26 | 29.96 | 30.00 | 30.36 | 29.97 | 29.82 | 29.97 | 29.74 | 29.89 | 29.98 |
| 1838 | 29.80 | 29.48 | 29.79 | 29.80 | 29.92 | 29.87 | 29.76 | 29.87 | 29.90 | 29.92 | 29.51 | 29.98 | 29.80 |
| 1839 | 29.84 | 29.90 | 29.82 | 30.06 | 29.99 | 29.80 | 29.85 | 29.97 | 29.62 | 30.02 | 29.67 | 29.66 | 29.85 |
| 1840 | 29.41 | 29.75 | 30.42 | 30.18 | 29,90 | 20.94 | 29.83 | 29.92 | 29.96 | 29.98 | 29.53 | 30.12 | 29.91 |
| Means. | 29.84 | 29.89 | 29.93 | 29.95 | 30.00 | 30.00 | 29.99 | 29.96 | 29.94 | 29.92 | 29.77 | 29.87 | 29.92 |
| Highest. | 30.26 | 30.33 | 30.42 | 30.26 | 30.24 | 30.34 | 30.36 | 30.13 | 30.11 | 30.17 | 30.19 | 30.22 | 30.04 |
| Lowest. | 29.41 | 29.37 | 29.46 | 29.52 | 29.85 | 29.78 | 29.76 | 29.57 | 29.62 | 29.70 | 29.51 | 29.49 | 29.80 |

The same Barometer has been used during the last twenty-two years as was in use the fifteen preceding years. It stands nearly 1-10th of an inch higher than other good Barometers do in the same situation, probably from some difference in the mercury. I find the allowance I have made in the scale for the rise and fall of the mercury in the reservoir is rather too small; consequently, the extreme elevations and depressions are not quite so great as they ought to be, but the influence of this circumstance upon the averages is scarcely worth notice.

Now, if we incorporate the means of the Barometer for twenty-two years, as above stated, with those of the former period of twenty-five years previously published, (see Vol. III. page 487,) so as to obtain general averages or means for both periods, amounting to forty-seven years, we shall obtain the following means for the different months, and the mean annual height of the Barometer for the whole period.

## TABLE

### OF THE MONTHLY MEAN HEIGHT OF THE BAROMETER FOR FORTY-SEVEN YEARS, FROM 1794 TO 1840 INCLUSIVE.

| | Inches. | Ins. |
|---|---|---|
| January | 29.80 | |
| February | 29.85 | 29.846. below the general mean. |
| March | 29.89 | |
| April | 29.90 | |
| May | 29.94 | 29.943. above the general mean. |
| June | 29.99 | |
| July | 29.94 | |
| August | 29.99 | 29.953. above the general mean. |
| September | 29.93 | |
| October | 29.85 | |
| November | 29.76 | 29.806. below the general mean. |
| December | 29.81 | |
| Annual mean for 47 years | 29.88 | |

In my former essay (see Manchester Memoirs, Vol. III. page 488, new series), I mentioned a remarkable fact deduced from the then observations of the Barometer, namely, that the altitude of the mercury was greater than the mean during the spring and summer months, and less than the mean during the autumnal and winter months, allowance being made for the effects of temperature. From the above table, the fact is

corroborated, although the annual mean, and also the mean of each month, except November, are higher than in the table, page 487 of the volume before mentioned.

The mean annual height of the Barometer for a series of years, does not differ much from the mean for any particular year. On looking over the annual means for the last forty-seven years, I find the lowest to have been in 1799 and 1800, both of which were 29.61 inches. These two years will long be remembered as the most unfavourable seasons for the produce of the earth that have occurred for half a century at least. The former of these was the coldest for the series of forty-seven years; and eighteen inches of rain fell in the three most important months of the year, viz. July, August, and September. The highest annual mean was in 1826, viz., 30.04 inches. This was one of three or four of the warmest in the above period of years. The greatest difference, therefore, between one year and another, appears to be .47 parts of an inch in this part of the earth, or parallel of latitude. There does not appear, however, to be a marked connexion between the annual pressure and temperature of the atmosphere, nor yet with the amount of rain.

It appears from the tables for the last forty-seven years, that the *highest* monthly mean height of the Barometer for a year, may occur in any one of the twelve months, but not indifferently. Thus I found the highest mean to occur six times in January, three times in February, five times in March, three times in April, three in May, four in June, five in July, seven in August, four in September, one in October, two in November, and four in December.

The above observation does not apply to the lowest monthly mean for any year:—for I found nine in January, six in February, five in March, three in April, one in June, one in September, six in October, ten in November, and six in December; none were found in May, July, or August—so that from March to October the lowest mean has occurred only five times, whilst from September to April it has occurred forty-two times in forty-seven years.

In this period of forty-seven years' observations the fact of greater variation of the Barometer in winter than in summer, may be supposed to have been sufficiently substantiated. On inspecting each year of the Journal, and marking those

months in which the *highest* rise of the mercury took place, and the *lowest* fall in the whole year, I find the number of such observations that have taken place in the respective months of the year as under.

There have 18 of the highest and lowest extremes occurred in ......... January,

| | |
|---|---|
| 10 | February, |
| 17 | March, |
| 6 | April, |
| 4 | May, |
| 1 | June, |
| 1 | July, |
| 0 | August, |
| 1 | September, |
| 10 | October, |
| 16 | November, |
| 21 | December, |
| 105 | |

One curious feature in the oscillations of the Barometer cannot fail to be noticed by every attentive observer. If the average height of the Barometer for any month be supposed thirty inches, and the highest extreme 30.5 inches, then the lowest extreme will mostly be about twenty-nine inches, or twice as far below the mean as the high extreme is above it.

I have not seen any recent attempts to explain the great leading facts of the variation of the Barometer. A considerable interest has of late been shewn by some Meteorologists, to ascertain the nature and magnitude of certain diurnal variations or oscillations of the Barometer. These were first observed, and are still most conspicuous in the Torrid Zone, but they have been traced into the northern and southern parts of the globe, only they are less easily perceived, by reason of the other greater causes of variation in those parts. Mr. James D. Forbes, Professor of Natural Philosophy in the University of Edinburgh, and Mr. Hudson, Assistant Secretary to the Royal Society, have distinguished themselves by making horary observations in reference to this subject.

## 2. Of the Thermometer.

Thermometers exposed to the weather are not so durable as Barometers, they are also more liable to accidents. My Thermometer has been renewed two or three times in the last 22 years; but care was taken to have it as correct as well could be. I have not used a Thermometer for registering the maximum and minimum tempera-

ture for many years, but one of the common construction. The situation of it was changed when I changed my residence, about 5 years ago, and is only about 100 yards from its former position; previous to its removal it was placed outside a window facing the S.E., 4 inches from the wall, and shaded from the sun, it has since been similarly placed near a window facing the N.W.; the daily observations were made at 8 a.m., and 1 and 11 p.m., the same as with the Barometer. The last 22 years have been warmer than the preceding 52, if the difference has not been occasioned in part by the change of the Instrument or its situation.

TABLE OF THE MEAN MONTHLY HEIGHTS AND MEAN ANNUAL HEIGHTS OF THE THERMOMETER FOR TWENTY-TWO YEARS, VIZ. FROM 1819 TO 1840 INCLUSIVE.

| Years. | Jan. | Feb. | Mar | Apr | May | Jun. | July | Aug | Sep. | Oct. | Nov | Dec | Annual Means. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 1819 | 39.5 | 38.8 | 44.7 | 47.4 | 51.5 | 56.8 | 63.8 | 64.4 | 56.9 | 49.6 | 39.9 | 34.8 | 49.0 |
| 1820 | 31.8 | 38.6 | 41.6 | 48.9 | 53.7 | 57.6 | 62.5 | 59.4 | 55.8 | 46.8 | 42.9 | 40.8 | 48.3 |
| 1821 | 38.8 | 36.1 | 42.1 | 50.1 | 50.6 | 56.3 | 60.8 | 62.0 | 58.6 | 51.5 | 47.3 | 43.2 | 49.7 |
| 1822 | 40.9 | 43.6 | 46.8 | 47.9 | 55.9 | 63.0 | 61 0 | 59.4 | 55.4 | 51.7 | 46.9 | 35.6 | 50.6 |
| 1823 | 32.9 | 37.5 | 42.1 | 45.1 | 55.2 | 55.1 | 58.0 | 58.8 | 55.5 | 48.4 | 46.1 | 42.0 | 48.0 |
| 1824 | 40.7 | 41.0 | 41.0 | 46.8 | 52.5 | 58.4 | 62.0 | 59.5 | 57.1 | 48.0 | 43.7 | 40.1 | 49.2 |
| 1825 | 38.1 | 38.3 | 42.0 | 48.0 | 54.0 | 56.0 | 63.5 | 62.0 | 60.0 | 51.4 | 40.7 | 40.6 | 49.5 |
| 1826 | 33.4 | 43.8 | 43.4 | 44.5 | 54.2 | 54.7 | 65.0 | 64.0 | 58.2 | 53.2 | 40.6 | 43.0 | 51.0 |
| 1827 | 35.6 | 34.3 | 43.0 | 48.9 | 54.6 | 58.2 | 63.0 | 63.0 | 57.4 | 53.6 | 45.2 | 44.9 | 50.1 |
| 1828 | 41.1 | 42.1 | 44.9 | 47.2 | 55.3 | 60.6 | 62.0 | 61.8 | 60.0 | 52.5 | 48.0 | 47.0 | 51.8 |
| 1829 | 34.1 | 41.4 | 41.6 | 46.1 | 57.1 | 60.8 | 63.1 | 59.5 | 54.5 | 49.4 | 42.6 | 37.4 | 48.9 |
| 1830 | 33.1 | 38.4 | 48.0 | 54.1 | 54.5 | 56.8 | 61.8 | 58.8 | 55.5 | 54.2 | 45.9 | 37.2 | 49.8 |
| 1831 | 36.6 | 42.6 | 46.4 | 50.3 | 55.2 | 61.4 | 63.0 | 63.8 | 58.0 | 56.2 | 43.9 | 44.7 | 51.8 |
| 1832 | 39.1 | 39.8 | 44.5 | 49.0 | 53.6 | 61.5 | 61.7 | 61.2 | 59.5 | 53.2 | 43.9 | 42.9 | 50.8 |
| 1833 | 36.1 | 43.1 | 40.5 | 47.5 | 62.1 | 60.6 | 64.0 | 60.4 | 55.5 | 51.8 | 44.8 | 45.9 | 51.0 |
| 1834 | 46.6 | 44.8 | 47.4 | 48.5 | 58.1 | 62.4 | 65.3 | 64.2 | 58.1 | 54.1 | 47.0 | 45.0 | 53.5 |
| 1835 | 39.9 | 43.9 | 44.8 | 49.0 | 53.8 | 59.8 | 62.3 | 64.1 | 58.1 | 49.5 | 46.5 | 41.0 | 50.9 |
| 1836 | 41.0 | 40.6 | 44.1 | 47.5 | 55.5 | 62.8 | 61.2 | 60.4 | 55.2 | 50.2 | 43.7 | 40.4 | 50.2 |
| 1837 | 38.7 | 42.1 | 37.8 | 42.1 | 52.7 | 62.5 | 64.4 | 62.9 | 56.8 | 52.6 | 43.0 | 43.8 | 49.9 |
| 1838 | 32.5 | 33.8 | 43.0 | 44.8 | 53.3 | 60.7 | 62.7 | 61.6 | 57.1 | 51.7 | 42.3 | 41.4 | 48.7 |
| 1839 | 40.1 | 40.7 | 40.6 | 46.3 | 53.9 | 60.4 | 62.1 | 63.0 | 56.7 | 52.0 | 47.6 | 40.5 | 50.3 |
| 1840 | 41.4 | 40.5 | 41.2 | 52.9 | 55.4 | 59.0 | 62.0 | 62.8 | 55.5 | 48.4 | 45.7 | 37.5 | 50.2 |
| Means. | 37.8 | 40.3 | 43.2 | 48.1 | 54.7 | 59.3 | 62.5 | 61.5 | 57.1 | 51.4 | 44.5 | 41.4 | 50.1 |
| Maxim | 46.6 | 44.8 | 48.0 | 54.1 | 62.8 | 64.7 | 65.3 | 64.2 | 60.0 | 56.2 | 48.0 | 45.9 | 53.5 |
| Minim. | 31.8 | 33.8 | 37.8 | 42.1 | 50.6 | 56.0 | 58.0 | 58.8 | 54.5 | 46.8 | 39.9 | 34.8 | 48.0 |

By uniting the preceding Table with that published in the Memoirs, Vol. III. page 494, we obtain the mean monthly and annual temperature of the atmosphere at Manchester for the last 47 years as follows:—

TABLE OF THE MONTHLY MEAN HEIGHT OF THE THERMOMETER, AND ALSO THE ANNUAL MEAN FROM 1794 TO 1840 INCLUSIVE.

| | | |
|---|---|---|
| January, ........36°.7 | May,............53°.2 | September, ....56°.3 |
| February, ......39.3 | June, ...........58.2 | October, .......50.0 |
| March, ..........41.8 | July, ............60.8 | November,.....42.9 |
| April, ...........47.1 | August, .........60.4 | December, ....39.0 |
| Annual Mean Temperature for 47 years,................48.8 | | |

The average Temperature of the year depends much on that of the winter months, which are so various in our climate. It is remarkable, that the mean Temperature of January 1795, was 24°.3, and that of the same month the following year was 44°, and in 1834 it was 46°.6, making a difference of the means in the same month to the amount of 22°.3. The corresponding differences in July do not exceed 10°.

January is the coldest month of the year, as might be expected, and the Temperature gradually increases with the approach of the Sun, till July, which is the warmest month of the year, but August is little inferior to it. After that the Temperature descends with greater rapidity than that of its ascent.

April and October are the months which approach nearest to the mean Temperature of the year, but the former is colder, and the latter warmer than the mean.

Rain is a great regulator of Temperature both in summer and winter. Rain is the cause of *cold* in summer, and of *heat* in winter: the reason is pretty obvious. Clouds in summer prevent the earth being heated by the sun's rays; and rain causes a copious evaporation, requiring a proportionate expenditure of heat. In winter the vapour is chiefly imported from the south and south-west, and being deposited here, the heat arising from the condensation of the vapour is diffused through the atmosphere, and the evaporation in that season being insignificant, it requires no material supply of heat. Hence we have a well founded maxim for this climate; *that a wet summer is a cold one, and a wet winter a warm one.*

## Of Rain.

It is well known that in some regions of the earth the vicissitudes of the seasons, especially as regards rain, may be predicted with tolerable certainty. Some months of the year are invariably rainy and others are mostly fair. But these characteristics do not apply to climates like ours situate in the middle of the Temperate Zone. Any one month in the year may be the wettest or driest in that year, for any thing that is previously known to the contrary. I have sometimes

been amused with making enquiries of persons of intelligence and observation, which months of the year they would judge, in a general way, to be the wettest and driest of the twelve, and have occasionally received for answer, that April was the wettest and October the driest; whereas, the very reverse appears to be the fact on reference to the average of a sufficiently long series of years.—

TABLE OF THE QUANTITY OF RAIN AT MAN[illegible]ER IN EACH MONTH FOR TWENTY TWO YEARS, FROM 1819 TO 1840 INCLUSIVE, AND THE TOTAL QUANTITY EACH YEAR; ALSO THE MONTHLY AND ANNUAL MEANS FOR THE SAME PERIOD

| Years | 1819 | 1820 | 1821 | 1822 | 1823 | 1824 | 1825 | 1826 | 1827 | 1828 | 1829 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Months | Inch | [illegible] | [illegible] | [illegible] | Inch | Inch | Inch | Inch | Inch | Inch | Inch |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 3.695 | 3.305 | 0.610 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.090 | 2.110 | 1.570 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 6.040 | 2.205 | 0.180 |
| April, | 2.320 | 3.282 | 3.984 | 1.514 | 2.298 | 2.154 | 2.010 | 2.095 | 1.365 | 3.525 | 3.110 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.850 | 1.170 | 1.210 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 0.260 | 1.870 | 2.720 | 2.870 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.225 | 11.480 | 5.480 |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 5.370 |
| Sept | 2.010 | 3.086 | 5.466 | 1.308 | 5.030 | 5.110 | 1.605 | [illegible] | 2.650 | 3.390 | 4.955 |
| Oct | 3.846 | 3.941 | [illegible] | 3.542 | 3.470 | 6.896 | 4.260 | [illegible] | 4.890 | 3.020 | [illegible] |
| Nov | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 5.510 | 7.375 | [illegible] | 3.050 | 3.697 | 4.345 |
| Dec | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 7.930 | 2.860 | [illegible] | 5.190 | 4.780 | 0.740 |
| Total, | 35.244 | 37.501 | 39.108 | 33.403 | 44.767 | 42.941 | [illegible] | 24.910 | [illegible] | [illegible] | 33.990 |

| Years | 1830 | 1831 | 1832 | 1833 | 1834 | 1835 | 1836 | 1837 | [illegible] | [illegible] | [illegible] | Means [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Months | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | [illegible] |
| [illegible] | 0.925 | 0.430 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.835 | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | 3.410 | 2.665 | [illegible] | [illegible] | 2.775 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | 1.330 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 1.730 | [illegible] | [illegible] | [illegible] | [illegible] |
| April, | [illegible] | 1.690 | 2.275 | 3.425 | 1.570 | 1.296 | 2.825 | 1.400 | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.301 | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 2.135 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | 2.610 | [illegible] | [illegible] | [illegible] | [illegible] | 2.935 | 1.870 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Sept | [illegible] | 2.355 | 1.025 | 3.085 | 3.410 | 5.440 | 4.406 | 1.860 | [illegible] | [illegible] | [illegible] | [illegible] |
| Oct | [illegible] | 4.105 | 4.025 | 3.530 | 1.760 | 4.005 | 3.580 | 4.877 | [illegible] | [illegible] | [illegible] | [illegible] |
| Nov | 3.965 | 6.520 | 5.180 | 4.575 | 1.690 | 3.690 | 7.230 | 4.530 | [illegible] | [illegible] | [illegible] | [illegible] |
| Dec | [illegible] | 3.275 | 4.852 | 7.060 | 1.275 | 1.720 | 4.035 | 3.070 | [illegible] | 1.720 | [illegible] | [illegible] |
| Total, | [illegible] | 35.434 | 36.642 | 41.677 | 34.670 | 36.536 | 45.351 | 33.137 | 31.418 | [illegible] | [illegible] | [illegible] |

been amused with making enquiries of persons of intelligence and observation, which months of the year they would judge, in a general way, to be the wettest and driest of the twelve, and have occasionally received for answer, that April was the wettest and October the driest; whereas, the very reverse appears to be the fact on reference to the average of a sufficiently long series of years.—

By connecting the preceding table with those previously published, (see Vol. V. page 668, and Vol. III. page 496, new series,) where the mean quantity of rain is given as under; we have the following results, viz.:—

For 8 years, from 1794 to 1801 inclusive.

| | Inches. | | Inches. |
|---|---|---|---|
| January, | 2.06 | July, | 3.51 |
| February, | 2.26 | August, | 3.73 |
| March, | 1.77 | September, | 4.16 |
| April, | 2.42 | October, | 3.96 |
| May, | 2.92 | November, | 3.14 |
| June, | 1.76 | December, | 2.91 |

Mean for the year, 34.60 inches.

For 17 years, from 1802 to 1818 inclusive.

| | Inches. | | Inches. |
|---|---|---|---|
| January, | 2.357 | July, | 3.349 |
| February, | 2.631 | August, | 3.109 |
| March, | 2.283 | September, | 2.431 |
| April, | 1.663 | October, | 3.628 |
| May, | 2.653 | November, | 3.490 |
| June, | 2.417 | December, | 3.585 |

Mean for the year, 33.596 inches.

For 47 years, from 1794 to 1840 inclusive.

| | Inches. | | Inches. |
|---|---|---|---|
| January, | 2.257 | July, | 3.706 |
| February, | 2.444 | August, | 3.478 |
| March, | 2.304 | September, | 3.195 |
| April, | 2.109 | October, | 3.733 |
| May, | 2.460 | November, | 3.710 |
| June, | 2.691 | December, | 3.431 |

Mean for the year, 35.518 inches.

On reference to the quantity of rain that has fallen at Manchester during the last 47 years, there is a remarkable difference in the average quantity for the various periods contained in the foregoing tables, which shows the importance of a long continued series of observations to obtain a satisfactory table of the mean quantity, either for each month or the whole year.

The rain in the first 6 months of the year is to that in the last 6 months, almost exactly as 2 to 3, on the general average, for the last 47 years; and, it cannot fail being remarked, that the transition from the wet period of the year to the dry one, and *vice versa*, is very abrupt. December is nearly the wettest month of the year, and January nearly the driest; there is $1\frac{2}{10}$ inch of rain of difference. Again, June is one of the dry periods, and July is eminently wet; the difference of the rain in these two successive months is 1 inch; this is about twice as great as any other difference in two successive months of the year.

In my former essay (see Vol. III. page 508, second series) I have advanced a reason which, indeed, is obvious to any one acquainted with the constitution of the atmosphere, why the first half

of the year should be the dry season and the last half the wet season. In January the portion of vapour in the atmosphere is small; the general temperature of the air is daily increasing till July, so as to enable it to support the quantity of vapour already in it, and to maintain the increasing portion also. But from July to January the extra quantity of vapour must fall in addition to the other causes of rain, which operate at all seasons of the year. This principle is general, and must operate in all parts of the earth. The *dry* seasons universally will be found to take place during the period the sun is approaching the Zenith, and the *wet* seasons during that period the sun is retreating from the Zenith. But the very abrupt transition from dry to wet in the months of June and July, and also from wet to dry in the months of December and January, is by no means so obvious. The maximum of Temperature takes place in July, and even sometimes in August.

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I have received from Thomas Fleming, Esq., a continuation of the account of rain which has fallen at different places on the line of the Rochdale Canal, (vide Vol. V. page 245, second series

of the Society's Memoirs), and also at some other places in the same direction, as well as at four places on the Ashton and Peak Forest Canal. The additional places on the Rochdale line are Blackstone Edge Toll Bar, at the foot of Blackstone Edge on the Yorkshire side of the hill, for 10 years. Ripponden, about half way between Blackstone Edge Toll Bar and Sowerby Bridge, for 9 years; and Slattocks, about 3 miles south of Moss Lock, for 8 years.

The observations on the line of the Ashton and Peak Forest Canal are for the year 1840 only, and are under the superintendence of Mr. Henry Wood, the Engineer. Fairfield is about 4 miles east of Manchester, and 320 feet above the sea. Marple is about 9 miles to the south of Fairfield, on the western side of the Derbyshire hills, and 531 feet above the sea. Comb's Reservoir is between Whaley Bridge and Chapel-en-le-Frith, S.E. of Marple about 6 miles, and surrounded by hills, and 850 feet above the sea:—and the Engine Station on the Peak Forest Railway is to the east of Comb's Reservoir, about 6 miles, or one mile S.E. of Chapel-en-le-Frith, and about 1121 feet above the sea.

TABLE OF THE FALL OF RAIN AT SLATTOCKS, ABOUT THREE MILES SOUTH OF MOSS LOCK, ON THE ROCHDALE CANAL. FOR EIGHT YEARS. (SEE VOL. V. PAGE 244.)

| | Jan. In. | Feb. In. | Mar In. | Apr In. | May In. | Jun. In. | July In. | Aug In. | Sep. In. | Oct. In. | Nov In. | Dec. In. | Ann. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1833 | 0.38 | 3.00 | 0 45 | 2.05 | 0.25 | 5.69 | 4.29 | 4.53 | 2.73 | 3.61 | 6.11 | 13.86 | 46.95 |
| 1834 | 8.22 | 3.10 | 1.83 | 0.77 | 0.60 | 2.50 | 5.30 | 2.26 | 1.70 | 1.30 | 1.53 | 0.85 | 29.96 |
| 1835 | 2.65 | 2.44 | 2.15 | 1.10 | 2.15 | 1.40 | 1.87 | 1.73 | 4.47 | 3.40 | 3.30 | 1.20 | 27.86 |
| 1836 | 1.70 | 2.00 | 3.10 | 2.50 | 0.20 | 3.15 | 4.60 | 1.41 | 3.05 | 2.30 | 5.30 | 3.30 | 32.61 |
| 1837 | 2.30 | 2.53 | 0.75 | 0.60 | 0.60 | 1.53 | 2.80 | 1.27 | 2.55 | 3.50 | 4.40 | 3.90 | 26.73 |
| 1838 | 0.75 | 0.50 | 1.10 | 2.05 | 2.30 | 3.25 | 2.30 | 4.60 | 0.75 | 3.50 | 2.70 | 1.70 | 25.50 |
| 1839 | 1.65 | 1.85 | 2.20 | 0.55 | — | 1.87 | 3.30 | 3.10 | 4.20 | 1.85 | 3.85 | 2.95 | 27.37 |
| 1840 | 4.20 | 1.50 | 0.30 | 0.42 | 2.90 | 2.90 | 4.90 | 2.70 | 3.50 | 1.50 | 3.50 | 0.25 | 28.57 |
| Means | 2.73 | 2.11 | 1.48 | 1.25 | 1.29 | 2.78 | 3.67 | 2.70 | 2.87 | 2.62 | 3.83 | 3.50 | 30.83 |

TABLE OF THE FALL OF RAIN AT MOSS LOCK, NEAR ROCHDALE. FOR ELEVEN YEARS. (SEE VOL. V. PAGE 244.)

| | Jan. In. | Feb. In. | Mar In. | Apr In. | May In. | Jun. In. | July In. | Aug In. | Sep. In. | Oct. In. | Nov In. | Dec. In. | Ann. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1830 | 0.20 | 2.60 | 1.10 | 2.45 | 2.40 | 3.00 | 4.70 | 2.40 | 5.45 | 1.35 | 3.95 | 1.20 | 30.80 |
| 1831 | 0.40 | 1.23 | 3.85 | 1.70 | 0.60 | 2.30 | 2.43 | 2.28 | 2.85 | 3.17 | 5.15 | 2.53 | 28.49 |
| 1832 | 1.20 | 0.59 | 2.35 | 1.82 | 1.87 | 2.67 | 1.65 | 4.18 | 0.86 | 3.56 | 3.80 | 4.25 | 28.80 |
| 1833 | 0.71 | 3.15 | 0.76 | 2.40 | 0.86 | 2.26 | 3.22 | 3.30 | 2.32 | 3.17 | 4.90 | 7.15 | 34.20 |
| 1834 | 6.25 | 2.57 | 2.28 | 0.91 | 0.64 | 2.65 | 4.75 | 2.00 | 1.83 | 1.76 | 2.59 | 1.02 | 29.25 |
| 1835 | 3.41 | 3.31 | 3.04 | 0.91 | 1.95 | 1.51 | 1.67 | 2.45 | 3.96 | 3.35 | 3.70 | 1.10 | 30.36 |
| 1836 | 2.42 | 2.10 | 3.70 | 2.21 | — | 3.75 | 4.95 | 1.73 | 3.30 | 3.10 | 6.60 | 4.65 | 38.51 |
| 1837 | 2.24 | 2.92 | 0.98 | 0.88 | 0.94 | 1.69 | 2.98 | 1.62 | 2.44 | 4.65 | 3.20 | 3.27 | 27.81 |
| 1838 | 0.54 | 1.15 | 1.92 | 2.60 | 2.85 | 3.00 | 3.23 | 3.95 | 0.98 | 3.50 | 1.67 | 1.75 | 27.14 |
| 1839 | 1.65 | 1.87 | 3.60 | 0.67 | 0.05 | 2.25 | 3.85 | 3.85 | 4.20 | 2.05 | 3.23 | 1.95 | 29.22 |
| 1840 | 3.17 | 0.85 | 0.15 | 0.35 | 2.53 | 2.20 | 3.85 | 3.48 | 3.28 | 1.30 | 3.18 | 0.05 | 24.39 |
| Means | 2.02 | 2.03 | 2 15 | 1.53 | 1.46 | 2.48 | 3.39 | 2.84 | 2.86 | 2.81 | 3.81 | 2.63 | 30.01 |

TABLE OF THE FALL OF RAIN AT WHITE HOLME RESERVOIR, SUMMIT OF BLACKSTONE EDGE. FOR ELEVEN YEARS. (SEE VOL. V. PAGE 243.)

| | Jan. | Feb. | Mar | Apr | May | Jun. | July | Aug | Sep. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| 1830 | 0.33 | 2.15 | 0.77 | 2.99 | 3.30 | 4.89 | 2.85 | 2.39 | 6.56 | 1.31 | 4.34 | 1.70 | 33.58 |
| 1831 | 0.72 | 1.46 | 3.98 | 2.33 | 0.52 | 1.90 | 3.72 | 2.95 | 4.65 | 4.36 | 5.96 | 4.60 | 37.15 |
| 1832 | 0.77 | 0.56 | 2.50 | 2.70 | 1.82 | 4.40 | 1.57 | 4.60 | 0.53 | 3.63 | 4.03 | 4.52 | 31.63 |
| 1833 | 0.53 | 4.07 | 1.38 | 3.59 | 1.12 | 4.21 | 2.60 | 3.94 | 2.64 | 3.90 | 6.72 | 12.67 | 47.37 |
| 1834 | 8.25 | 6.05 | 4.20 | 0.97 | 0.80 | 3.30 | 6.05 | 2.70 | 2.39 | 1.50 | 2.58 | 1.15 | 39.94 |
| 1835 | 2.76 | 4.50 | 3.72 | 1.54 | 2.80 | 1.65 | 1.40 | 1.60 | 5.90 | 5.45 | 4.08 | 1.08 | 36.43 |
| 1836 | 3.25 | 2.06 | 4.50 | 2.15 | 0 25 | 4.40 | 6.75 | 2.25 | 2.90 | 3.70 | 6.14 | 2,90 | 41.25 |
| 1837 | 4.05 | 4.50 | 0.44 | 0.43 | 1.05 | 2.83 | 2.75 | 1.52 | 4.03 | 6.07 | 4.90 | 5.60 | 38.17 |
| 1838 | 0.40 | 0.20 | 2.25 | 1.90 | 2.80 | 3.80 | 3.80 | 6.40 | 1.30 | 4.65 | 3.00 | 2.05 | 32.55 |
| 1839 | 2.07 | 3.00 | 4.50 | 1.25 | — | 2.72 | 4.00 | 3.28 | 5.02 | 2.40 | 4.60 | 2.95 | 35.79 |
| 1840 | 6.40 | 2.60 | 0.20 | 0.15 | 3.40 | 2.40 | 4.70 | 4.60 | 5.00 | 2.08 | 5 02 | 0.35 | 36.90 |
| Means. | 2.68 | 2.83 | 2.58 | 1.81 | 1.78 | 3.32 | 3.65 | 3.30 | 3.72 | 3.55 | 4.66 | 3.60 | 37.48 |

TABLE OF THE FALL OF RAIN AT STUBBINS, NEAR TODMORDEN. FOR ELEVEN YEARS. (SEE VOL. V. PAGE 244.)

| | Jan. | Feb. | Mar | Apr | May | Jun. | July | Aug | Sep. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| 1830 | 0.27 | 2.90 | 0.72 | 3 67 | 3.08 | 5.53 | 4.33 | 2.61 | 6.47 | 0.80 | 5.89 | 1.08 | 37.32 |
| 1831 | 0.36 | 1.98 | 3.56 | 0.95 | 0.39 | 2.22 | 1.32 | 2.52 | 2.60 | 3.50 | 6.12 | 3.75 | 29.27 |
| 1832 | 0.55 | 0.02 | 1.56 | 1.89 | 1.21 | 3.22 | 1.23 | 2.88 | 0.66 | 3.29 | 4.46 | 5.13 | 26.10 |
| 1833 | 0.28 | 3.45 | 1.19 | 2.80 | 0.66 | 4.79 | 2.56 | 3.22 | 1.85 | 3.43 | 4.45 | 9.72 | 38.40 |
| 1834 | 7.94 | 2.83 | 2.89 | 0.81 | 0.72 | 2.01 | 3.53 | 1.79 | 2.72 | 1.55 | 2.75 | 1.27 | 30.81 |
| 1835 | 3.19 | 5.49 | 3.46 | 1.07 | 1.55 | 1.43 | 1.09 | 1.28 | 4.49 | 3.84 | 3.33 | 0.62 | 30.84 |
| 1836 | 2.40 | 2.09 | 5.21 | 2.55 | 0.05 | 3.74 | 3.74 | 1.50 | 3.05 | 4.01 | 7.14 | 4.70 | 40.18 |
| 1837 | 3.06 | 3.97 | 0.78 | 1.15 | 0.56 | 1.87 | 2.78 | 0.90 | 2.52 | 5.36 | 4.80 | 4.58 | 32.33 |
| 1838 | 0.55 | 1.10 | 1.63 | 1.07 | 3.73 | 2.52 | 1.42 | 4.34 | 0.82 | 6.00 | 2.57 | 1.88 | 27.63 |
| 1839 | 2.00 | 2.22 | 3.22 | 0 74 | — | 2.90 | 4.26 | 2.76 | 5.47 | 1.84 | 4.07 | 2.84 | 32.32 |
| 1840 | 5.85 | 1.88 | — | 0.44 | 2.68 | 2.23 | 4.95 | 3.00 | 4.68 | 1.27 | 3.46 | 0.04 | 30.48 |
| Means. | 2.40 | 2 54 | 2.38 | 1.56 | 1.33 | 2.77 | 2.84 | 2.43 | 3.21 | 3.17 | 4.46 | 3.24 | 32.33 |

TABLE OF THE FALL OF RAIN AT SOWERBY BRIDGE. FOR ELEVEN YEARS.

(SEE VOL V. PAGE 244.)

| | Jan. | Feb. | Mar | Apr | May | Jun. | July | Aug | Sep. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| 1830 | 1.07 | 2.45 | 0.57 | 1.95 | 3 28 | 4.30 | 3.42 | 2.27 | 4.76 | 0.45 | 3.84 | 1.90 | 30.26 |
| 1831 | 1.12 | 2.08 | 2.48 | 1.70 | 0.81 | 1.56 | 3.89 | 2.31 | 2.72 | 3.42 | 5.06 | 2.57 | 29.72 |
| 1832 | 1.08 | 0.24 | 1.44 | 2.32 | 1.92 | 4.37 | 1.19 | 4.11 | 0.30 | 2.10 | 3.22 | 4.85 | 27.14 |
| 1833 | 1.10 | 2.58 | 1.24 | 2.51 | 1.02 | 4.74 | 1.30 | 3.58 | 2.25 | 2.55 | 2.87 | 5.03 | 30.77 |
| 1834 | 4.74 | 1.89 | 1.71 | 1.32 | 0.42 | 1.32 | 5.72 | 1.34 | 2.26 | 0.71 | 2.08 | 0.80 | 24.31 |
| 1835 | 2.70 | 2.92 | 2.65 | 1.76 | 1.84 | 0.96 | 0.39 | 1.59 | 3.56 | 4.03 | 3.04 | 0.40 | 25.84 |
| 1836 | 1.56 | 1.70 | 3.92 | 1.85 | — | 4.29 | 2.64 | 1.15 | 3.21 | 2.95 | 5.30 | 2.70 | 31.29 |
| 1837 | 2.64 | 2.94 | 0.68 | 1.15 | 0.57 | 1.85 | 2.80 | 1.10 | 2.15 | 3.63 | 2.63 | 4.36 | 26.50 |
| 1838 | 0.64 | 2.06 | 1.15 | 1.13 | 3.15 | 3.55 | 2.20 | 2.70 | 0.70 | 5.17 | 2.05 | 1.40 | 25.90 |
| 1839 | 2.20 | 1.15 | 2 40 | 0.40 | — | 3.90 | 4.00 | 2.60 | 3.45 | 2.00 | 3.70 | 2.20 | 28.00 |
| 1840 | 3.71 | 1.10 | 0.10 | 0.50 | 2.05 | 1.80 | 2.50 | 1.80 | 3.25 | 1.13 | 3.70 | 0.15 | 21.79 |
| Means | 2.05 | 1.92 | 1.67 | 1.51 | 1.37 | 2.96 | 2.73 | 2.23 | 2.60 | 2.56 | 3.41 | 2.40 | 27.41 |

TABLE OF THE FALL OF RAIN AT THE TOLL BAR, EAST SIDE OF BLACKSTONE EDGE. FOR TEN YEARS.

| | Jan. | Feb. | Mar | Apr | May | Jun. | July | Aug | Sep. | Oct. | Nov | Dec. | Ann. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| 1831 | 0.83 | 2.89 | 4.93 | 2.21 | 1.30 | 2.08 | 3.41 | 2.59 | 3.63 | 4.22 | 6.58 | 4.24 | 38.91 |
| 1832 | 1.14 | 0.54 | 2.77 | 2.60 | 2.12 | 4.66 | 1.60 | 4.50 | 1.04 | 3.72 | 4.37 | 5.42 | 34.48 |
| 1833 | 0.38 | 4.09 | 1.33 | 3.53 | 0.99 | 5.72 | 1.85 | 3.80 | 3.05 | 4.12 | 6.25 | 8.07 | 43.18 |
| 1834 | 7.53 | 4.05 | 3.95 | 0.50 | 0.55 | 2.75 | 5.67 | 2.08 | 2.80 | 2.12 | 3.45 | 0.44 | 35.89 |
| 1835 | 2.15 | 4.00 | 4.04 | 1.50 | 2.50 | 1.70 | 1.22 | 1.40 | 5.40 | 5.00 | 3.85 | 1.35 | 34.11 |
| 1836 | 3.07 | 2.80 | 4 80 | 2.53 | — | 4.15 | 5.60 | 1.57 | 3.07 | 3.98 | 5.25 | 2.50 | 39.26 |
| 1837 | 3.53 | 4.00 | 0.71 | 0.38 | 0.60 | 2.93 | 2.83 | 1.00 | 3.07 | 6.00 | 4.05 | 5.07 | 34.17 |
| 1838 | 0.80 | — | 2.30 | 2.15 | 3.07 | 3.30 | 3.13 | 6.03 | 1.15 | 5.80 | 2.90 | 2.80 | 33.43 |
| 1839 | 2.80 | 1.70 | 3.90 | 0.95 | — | 2.80 | 4.25 | 3.28 | 5.25 | 2.60 | 5.02 | 3.15 | 35.70 |
| 1840 | 5.70 | 2.62 | 0.27 | 0.25 | 3.30 | 2.36 | 4.30 | 4.15 | 4.30 | 1.70 | 5.20 | 0.25 | 34.40 |
| Means | 2.79 | 2.67 | 2.90 | 1.66 | 1.44 | 3.24 | 3.39 | 3.04 | 3.28 | 3.92 | 4.69 | 3.33 | 36.35 |

TABLE OF THE FALL OF RAIN AT RIPPONDEN, IN YORKSHIRE, ON THE EAST OF BLACKSTONE EDGE. FOR NINE YEARS.

| | Jan. In. | Feb. In. | Mar In. | Apr In. | May In. | Jun. In. | July In. | Aug In. | Sep. In. | Oct. In. | Nov In. | Dec. In. | Ann. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1832 | 0.60 | 0.40 | 1.92 | 2.25 | 2.16 | 4 20 | 1.57 | 4.40 | 0.63 | 3.04 | 3.18 | 4.30 | 28.65 |
| 1833 | 0.23 | 3.52 | 1.00 | 2.13 | 0.75 | 5.54 | 1.80 | 3.25 | 2.03 | 3.70 | 5.57 | 9.75 | 39.27 |
| 1834 | 6.67 | 3.80 | 3.62 | 1.25 | 0.60 | 2.00 | 5.80 | 2 00 | 2.47 | 1.02 | 3.40 | 1.07 | 33.70 |
| 1835 | 2.56 | 3.75 | 3.06 | 1.70 | 2.25 | 1.65 | 1.15 | 1.25 | 5.60 | 4.75 | 3.75 | 0.80 | 32.27 |
| 1836 | 2.25 | 1.75 | 4.05 | 2.05 | — | 4.00 | 4.95 | 1.60 | 2.50 | 3.50 | 5.72 | 2.25 | 34.62 |
| 1837 | 3.72 | 3.72 | 0.27 | 0.31 | 0.67 | 2.30 | 2.95 | 1.70 | 3.06 | 5.80 | 4.30 | 4.80 | 33.60 |
| 1838 | 0.25 | — | 2.00 | 1.60 | 2.50 | 3.09 | 3.00 | 5.80 | 0.90 | 5.30 | 2.60 | 1.90 | 28.94 |
| 1839 | 2.20 | 2.50 | 3 50 | 0.60 | — | 3.25 | 3.50 | 3.50 | 5,30 | 2.05 | 4.30 | 2.62 | 33.32 |
| 1840 | 6.15 | 2.40 | 0.14 | 0.15 | 3.68 | 2.31 | 4.50 | 4.45 | 4.90 | 2.00 | 4.80 | 0.40 | 35.88 |
| Means. | 2.73 | 2.73 | 2.17 | 1.34 | 1.80 | 3.15 | 3.24 | 3.10 | 3.04 | 3.46 | 4.18 | 3.10 | 34.04 |

TABLE OF THE FALL OF RAIN AT FOUR PLACES ON THE LINE OF THE ASHTON AND PEAK FOREST CANAL, FOR THE YEAR 1840.

| | Fairfield. | Marple. | Comb's Reservoir. | Engine Station, near Chapel-en-le-Frith. |
|---|---|---|---|---|
| | In. | In. | In. | In. |
| January .......... | 2.06 | 1.26 | 3.18 | 4.80 |
| February ........ | 0.75 | 0.53 | 1.99 | 2.00 |
| March .......... | 0.25 | 0.19 | 0.33 | 1.50 |
| April ............ | 0.38 | 0.42 | 0.68 | 1.10 |
| May ............ | 2.97 | 2.02 | 1.88 | 2.08 |
| June ............ | 2.55 | 2.26 | 3.81 | 4.09 |
| July ............ | 4.07 | 4.24 | 5.18 | 7.20 |
| August .......... | 4.55 | 3.61 | 5.22 | 8.02 |
| September........ | 2.99 | 3.09 | 3.71 | 5.01 |
| October.......... | 1.80 | 1.54 | 2.18 | 3.01 |
| November ........ | 3.29 | 2.54 | 4.87 | 8.07 |
| December ........ | 0.42 | 0.40 | 0.35 | 1 60 |
| Total ........ | 26.08 | 22.10 | 33.38 | 48.48 |

Mr. Henry Hough Watson of Bolton-le-Moors has forwarded to me the particulars of his observations on the Barometer and Thermometer, and also the quantity of rain, &c., for 10 years, which are arranged in the following tables.

The town of Bolton is about 320 feet above the sea, and situated 11 miles north-west of Manchester, below a range of hills commencing about south-east, and passing to a little west of north; the summits of these hills are from 3 to 6 miles from the town, and rise to an elevation of from 400 to 1000 feet above it. The country towards the south and west is very flat to the distance of 30 or 40 miles, and therefore the immediate neighbourhood of the town is exposed to the currents of air from that direction.

MR. HENRY HOUGH WATSON'S ACCOUNT OF THE MEAN HEIGHT OF THE BAROMETER AT BOLTON, DURING TEN YEARS.

| Yrs. | Jan. | Feb. | Mar. | April | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1831 | 29.59 | 29.33 | 29.39 | 29.39 | 29.42 | 29.18 | 29.30 | 29.34 | 29.20 | 29.26 | 29.44 | 29.20 | 29.34 |
| 1832 | 29.38 | 29.35 | 29.30 | 29.55 | 29.40 | 29.50 | 29.60 | 29.35 | 29.69 | 29.40 | 29.53 | 29.31 | 29.45 |
| 1833 | 29.85 | 29.10 | 29.55 | 29.40 | 29.74 | 29.43 | 29.68 | 29.62 | 29.57 | 29.46 | 29.51 | 29.27 | 29.51 |
| 1834 | 29.30 | 29.75 | 29.84 | 29.86 | 29.72 | 29.64 | 29.66 | 29.57 | 29.76 | 29.71 | 29.63 | 29.97 | 29.70 |
| 1835 | 29.74 | 29.43 | 29.63 | 29.84 | 29.57 | 29.78 | 29.74 | 29.71 | 29.38 | 29.46 | 29.60 | 29.87 | 29.65 |
| 1836 | 29.55 | 29.52 | 29.16 | 29.56 | 29.98 | 29.58 | 29.65 | 29.75 | 29.57 | 29.49 | 29.27 | 29.50 | 29.55 |
| 1837 | 29.64 | 29.58 | 29.70 | 29.52 | 29.68 | 29.73 | 29.68 | 29.72 | 29.61 | 29.77 | 29.50 | 29.63 | 29.65 |
| 1838 | 29.63 | 29.33 | 29.51 | 29.51 | 29.65 | 29.58 | 29.68 | 29.58 | 29.71 | 29.66 | 29.24 | 29.74 | 29.57 |
| 1839 | 29.56 | 29.63 | 29.52 | 29.82 | 29.74 | 29.64 | 29.57 | 29.70 | 29.31 | 29.75 | 29.40 | 29,38 | 29.59 |
| 1840 | 29.40 | 29.62 | 30.02 | 29.81 | 29.62 | 29.65 | 29.56 | 29.65 | 29.48 | 29.71 | 29.31 | 29.87 | 29.64 |
| Mn. | 29.56 | 29.46 | 29.56 | 29.63 | 29.65 | 29.57 | 29.61 | 29.60 | 29.53 | 29.57 | 29.44 | 29.57 | 29.56 |
| Max. | 29.85 | 29.75 | 30.02 | 29.86 | 29.98 | 29.78 | 29.74 | 29.75 | 29.76 | 29.77 | 29.63 | 29.97 | |
| Min. | 29.30 | 29.10 | 29.16 | 29.39 | 29.40 | 29.18 | 29.30 | 29.34 | 29.20 | 29.26 | 29.24 | 29.20 | |

MR. HENRY HOUGH WATSON'S ACCOUNT OF THE MEAN HEIGHT OF THE THERMOMETER, AT BOLTON, DURING TEN YEARS.

| Years. | Jan. | Feb. | Mar. | Apr. | May | June | July. | Aug. | Sep. | Oct. | Nov. | Dec. | Mn. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1831 | 34° | 42° | 57° | 54° | 58° | 61° | 67° | 65° | 57° | 54° | 39° | 40° | 52° |
| 1832 | 38 | 40 | 46 | 52 | 55 | 62 | 64 | 63 | 62 | 54 | 42 | 40 | 51 |
| 1833 | 35 | 42 | 40 | 47 | 59 | 58 | 62 | 57 | 54 | 50 | 44 | 43 | 49 |
| 1834 | 44 | 42 | 45 | 46 | 57 | 59 | 64 | 61 | 58 | 51 | 45 | 44 | 51 |
| 1835 | 36 | 42 | 43 | 47 | 51 | 60 | 62 | 63 | 56 | 47 | 44 | 38 | 49 |
| 1836 | 39 | 39 | 41 | 45 | 54 | 59 | 59 | 59 | 53 | 48 | 41 | 39 | 48 |
| 1837 | 37 | 41 | 37 | 41 | 49 | 63 | 62 | 60 | 56 | 50 | 42 | 42 | 48 |
| 1838 | 30 | 32 | 40 | 43 | 52 | 57 | 60 | 59 | 56 | 49 | 40 | 39 | 46 |
| 1839 | 36 | 39 | 40 | 44 | 51 | 57 | 59 | 58 | 54 | 49 | 45 | 38 | 47 |
| 1840 | 39 | 38 | 40 | 51 | 53 | 57 | 57 | 61 | 51 | 47 | 43 | 36 | 48 |
| Mean | 37 | 40 | 43 | 47 | 54 | 59 | 62 | 61 | 56 | 50 | 42 | 40 | 49 |
| Maxim | 44 | 42 | 57 | 54 | 59 | 63 | 67 | 65 | 62 | ·54 | 45 | 44 | |
| Minim | 30 | 32 | 37 | 41 | 49 | 57 | 57 | 57 | 51 | 47 | 39 | 36 | |

MR. HENRY HOUGH WATSON'S ACCOUNT OF THE FALL OF RAIN AT BOLTON, DURING TEN YEARS.

| | 1831. | 1832. | 1833. | 1834. | 1835 | 1836. | 1837. | 1838. | 1839 | 1840. | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January .... | 1.44 | 2.49 | 1.46 | 8.92 | 5.10 | 5.05 | 3.54 | 3.80 | 7.27 | 6.04 | 7.33 |
| February .. | 4.27 | 0.81 | 4.74 | 3.60 | 4.98 | 3.36 | 4.40 | | | 2.10 | |
| March .... | 4.97 | 2.84 | 1.42 | 3.07 | 4.91 | 5.31 | 1.41 | 3.04 | 5.01 | 0.73 | 3.27 |
| April ...... | 2.16 | 3.87 | 3.20 | 1.86 | 1.23 | 4.37 | 2.02 | 3.94 | 1.03 | 1.36 | 2.50 |
| May ...... | 0.62 | 6.07 | 0.66 | 1.65 | 2.93 | 0.18 | 1.57 | 3.89 | 0.53 | 4.50 | 2.26 |
| June ...... | 3.60 | 7.94 | 7.06 | 3.67 | 2.50 | 3.93 | 2.61 | 6.64 | 3.14 | 4.35 | 4.54 |
| July ...... | 12.02 | 3.73 | 3.57 | 6.88 | 3.16 | 5.76 | 3.12 | 4.43 | 6.59 | 6.65 | 5.59 |
| August .... | 6.27 | 5.83 | 4.80 | 3.66 | 2.03 | 2.82 | 2.86 | 6.94 | 3.55 | 5.37 | 4.41 |
| September. . | 5.57 | 1.75 | 3.07 | 3.29 | 7.43 | 4.30 | 3.52 | 1.80 | 6.95 | 4.72 | 4.24 |
| October.... | 7.51 | 6.48 | 4.75 | 2.38 | 5.41 | 4.21 | 5.98 | 7.83 | 2.78 | 3.22 | 5.05 |
| November .. | 9.85 | 5.38 | 6.50 | 3.41 | 4.80 | 8.71 | 6.10 | 2.90 | 5.22 | 5.57 | 5.84 |
| December .. | 4.02 | 6.58 | 10.47 | 1.59 | 1.96 | 5.78 | 5.12 | 2.64 | 3.19 | 0.42 | 4.17 |
| Total .. | 62.30 | 53.77 | 51.70 | 43.98 | 46.44 | 53.78 | 42.25 | 47.85 | 45.26 | 45.03 | 49.20 |

MR. HENRY HOUGH WATSON'S ACCOUNT OF THE MEAN VAPOUR POINT AT BOLTON, DEDUCED FROM OBSERVATIONS MADE DAILY AT NOON, DURING NINE YEARS.*

| Years. | Jan. | Feb. | Mar. | Apr. | May. | June | July | Aug. | Sept | Oct. | Nov. | Dec. | Mn. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1831 | 32° | 40° | 44° | 47° | 50° | 57° | 57° | 57° | 53° | 52° | 44° | 42° | 48° |
| 1832 | 37 | 36 | 42 | 45 | 49 | 57 | 59 | 52 | 56 | 51 | 42 | 40 | 47 |
| 1833 | 32 | 41 | 37 | 44 | 54 | 54 | 58 | 50 | 49 | 47 | 43 | 42 | 46 |
| 1834 | 42 | 39 | 41 | 40 | 49 | 52 | 58 | 55 | 53 | 48 | 42 | 41 | 47 |
| 1835 | 34 | 40 | 40 | 43 | 48 | 51 | 55 | 58 | 51 | 46 | 43 | 38 | 46 |
| 1836 | 38 | 39 | 40 | 42 | 45 | 52 | 53 | 54 | 48 | 45 | 41 | 38 | 45 |
| 1837 | 35 | 41 | 35 | 38 | 44 | 52 | 57 | 54 | 51 | 49 | 41 | 45 | 45 |
| 1838 | 30 | 32 | 40 | 42 | 43 | 52 | 54 | 55 | 54 | 46 | 39 | 39 | 44 |
| 1839 | 36 | 38 | 39 | 40 | 46 | 53 | 55 | 54 | 53 | 46 | 43 | 38 | 45 |
| Mean | 35 | 38 | 40 | 42 | 48 | 53 | 56 | 54 | 52 | 48 | 42 | 40 | 46 |
| Maxm. | 42 | 41 | 44 | 47 | 54 | 57 | 59 | 58 | 56 | 52 | 44 | 45 | 48 |
| Minim. | 30 | 32 | 35 | 38 | 43 | 51 | 53 | 50 | 48 | 45 | 39 | 38 | 44 |

* He determines the vapour point by the means recommended by me, *Man. Memoirs*, vol. 5, *Old Series*, page 582.

MR. HENRY HOUGH WATSON'S ACCOUNT OF THE EVAPORATION OF WATER FROM A CYLINDRICAL VESSEL OF TEN INCHES DIAMETER, KEPT NEARLY FULL, AT BOLTON.

| | 1831. | 1832. | 1833. | 1834. | 1835. | 1836. | 1837. | 1838. | 1839. | 1840. | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January | — * | 0.24 | 0.22 | 0.78 | 0.50 | 0.64 | 0.24 | 0.84 | — | — | — |
| February | — | 0.47 | 0.97 | 1.25 | 1.26 | 0.80 | 0.81 | | | | |
| March.... | 1.12 | 0.89 | 1.03 | 2.08 | 1.81 | 1.74 | 0.63 | 1.15 | — | — | — |
| April ... | 1.27 | 2.08 | 1.84 | 2.46 | 2.29 | 2.58 | 1.47 | 1.63 | 2.32 | — | — |
| May.... | 2.51 | 4.13 | 4.29 | 4.18 | 2.34 | 5.36 | 1.92 | 3.02 | 4.17 | 3.28 | 3.52 |
| June.... | 3.40 | 4.06 | 3.83 | 3.66 | 4.08 | 3.41 | 3.69 | 2.85 | 3.75 | 3.07 | 3.58 |
| July.... | 5.12 | 3.74 | 3.88 | 3.85 | 4.46 | 3.56 | 2.82 | 2.69 | 3.57 | 4.27 | 3.77 |
| August .. | 2.94 | 2.21 | 2.72 | 2.36 | 2.89 | 2.30 | 2.39 | 1.95 | 2.10 | 3.52 | 2.54 |
| Septem. | 1.84 | 1.67 | 1.85 | 1.09 | 1.95 | 1.45 | 1.21 | 2.08 | 2.55 | 1.80 | 1.75 |
| October. | 1.29 | 2.06 | 1.87 | 1.02 | 0.98 | 0.95 | 0.85 | 2.64 | 1.87 | 1.35 | 1.49 |
| Novem.. | 0.84 | 0.37 | 1.12 | 0.90 | 0.80 | 1.04 | 0.52 | 0.82 | 0.94 | 1.07 | 0.84 |
| Decem.. | 0.46 | 0.43 | 0.61 | 0.55 | 0.42 | 0.53 | 0.57 | 0.49 | 0.91 | — | — |
| | | 22.35 | 24.23 | 24.18 | 23.78 | 24.36 | 17.12 | 20.16 | | | |

* The gauge in the winter season sometimes got damaged by the frost; and, in consequence, the amount of evaporation could not be determined.

I have received from Thomas Ashton Esq. of Hyde, the following account of the quantity of rain which has fallen near his residence. The township of Hyde, in Cheshire, is about eight miles east of Manchester, and the line of the Peak Forest Canal passes through it a short distance from Mr. Ashton's house, at an elevation of 320 feet above the sea. Hyde is situated on the west side, and towards the bottom of the range of hills which occupy the north east part of Cheshire, and west of Derbyshire, and in the latter county rise to the height of 2000 feet above the sea. The country to the west is a flat plane, extending to the sea, at the distance of upwards of forty miles.

TABLE OF THE FALL OF RAIN, TAKEN IN THE GARDEN OF THOMAS ASHTON, ESQ. OF HYDE, IN CHESHIRE, FOR TEN YEARS.

| | Jan. In. | Feb. In. | Mar. In. | April In. | May. In. | June. In. | July. In. | Aug. In. | Sept. In. | Oct. In. | Nov. In. | Dec. In. | Ann. In. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1831 | 0.4 | 2.3 | 3.3 | 0.9 | 1.8 | 2.7 | 4.5 | 2.5 | 0.9 | 4.4 | 5.7 | 2.1 | 31.4 |
| 1832 | 1.0 | 0.4 | 2.2 | 2.4 | 1.2 | 5.2 | 2.4 | 2.5 | 3.0 | 2.5 | 3.6 | 5.7 | 32.1 |
| 1833 | 0.5 | 3.2 | 1.3 | 2.3 | 2.1 | 7.1 | 2.9 | 4.8 | 2.9 | 3.2 | 4.5 | 6.3 | 41.1 |
| 1834 | 4.3 | 2.1 | 3.1 | 1.6 | 0.8 | 2.7 | 6.1 | 1.8 | 2.5 | 2.0 | 1.7 | 1.0 | 29.7 |
| 1835 | 4.0 | 2.9 | 3.0 | 1.6 | 2.5 | 1.7 | 1.7 | 3.2 | 4.3 | 4.3 | 3.1 | 1.6 | 33.9 |
| 1836 | 2.9 | 3.6 | 4.4 | 2 8 | 0.2 | 4.0 | 3.4 | 2.2 | 4.9 | 2.7 | 7.3 | 4.1 | 42.5 |
| 1837 | 3.2 | 2.8 | 1.3 | 1.8 | 1.4 | 1.9 | 3.4 | 2.8 | 2.6 | 5.0 | 4.8 | 3.9 | 34.9 |
| 1838 | 0.9 | 1.3 | 2.4 | 3.7 | 3.8 | 4.6 | 3.8 | 5.8 | 1.4 | 4.4 | 2.6 | 0.9 | 35.6 |
| 1839 | 2.8 | 2.0 | 3.4 | 0.9 | 0.5 | 4.1 | 3.8 | 4.5 | 5.2 | 2.9 | 3.8 | 2.2 | 36.1 |
| 1840 | 4.0 | 1.5 | — | 0.6 | 3.5 | 3.5 | 6.4 | 5.0 | 3.9 | 2.1 | 4.9 | 0.3 | 35.7 |
| Means | 2.4 | 2.2 | 2.4 | 1.9 | 1.8 | 3.7 | 3.8 | 3.5 | 3.2 | 3.4 | 4.2 | 2.8 | 35.3 |

COMPARATIVE TABLE OF THE MEAN MONTHLY AND ANNUAL QUANTITIES OF RAIN, AT VARIOUS PLACES IN THE NEIGHBOURHOOD OF MANCHESTER; AND ALSO IN LONDON: BEING THE AVERAGES FOR MANY YEARS, EXCEPT THOSE ON THE LINE OF THE PEAK FOREST CANAL.

| | Manchester. 47 years. | Bolton. 10 years. | On the line or near the Rochdale Canal. | | | | | | | On the line of the Ashton and Peak Forest Canal. | | | | | General Average. | London. 62 years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Slattocks. 8 years. | Moss Lock. 16 years. | Summit of Blackstone Edge. 21 years. | Stubbins. 16 years. | Sowerby Bridge. 13 years. | Toll bar, east side Blackstone Edge. 10 years. | Ripponden. 9 years. | Hyde. 10 years. | Fairfield. 1 year. | Marple. 1 year. | Comb's Reservoir. 1 year. | One mile S. E. of Chapel-le-Frith. 1 year. | | |
| | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. | Inch. |
| January .... | 2.257 | } 7.33 | {2.73 | 1.86 | 2.15 | 2.24 | 2.01 | 2.79 | 2.73 | 2.40 | 2.06 | 1.26 | 3.18 | 4.80 | 2.56 | 1.291 |
| February .. | 2.444 | | {2.11 | 1.79 | 2.33 | 2.41 | 1.83 | 2.67 | 2.73 | 2.20 | 0.75 | 0.53 | 1.99 | 2.00 | 2.12 | 1.166 |
| March ..... | 2.304 | 3.27 | 1.48 | 1.80 | 2.26 | 2.20 | 1.52 | 2.90 | 2.17 | 2.40 | 0.25 | 0.19 | 0.33 | 1.50 | 1.76 | 1.063 |
| April ...... | 2.109 | 2.50 | 1.25 | 1.61 | 2.08 | 1.85 | 1.83 | 1.66 | 1.34 | 1.90 | 0.38 | 0.42 | 0.68 | 1.10 | 1.48 | 1.245 |
| May ...... | 2.460 | 2.26 | 1.29 | 1.31 | 1.73 | 1.47 | 1.28 | 1.44 | 1.80 | 1.80 | 2.97 | 2.02 | 1.88 | 2.08 | 1.84 | 1.482 |
| June ...... | 2.691 | 4.54 | 2.78 | 2.25 | 2.53 | 2.44 | 2.83 | 3.24 | 3.15 | 3.70 | 2.55 | 2.26 | 3.81 | 4.09 | 3.06 | 1.700 |
| July ...... | 3.706 | 5.59 | 3.67 | 3.38 | 3.28 | 2.79 | 3.09 | 3.39 | 3.24 | 3.80 | 4.07 | 4.24 | 5.18 | 7.20 | 4.04 | 2.224 |
| August .... | 3.478 | 4.41 | 2.70 | 3.14 | 3.51 | 2.97 | 2.64 | 3.04 | 3.10 | 3.50 | 4.55 | 3.61 | 5.22 | 8.02 | 3.85 | 1.710 |
| September.. | 3.195 | 4.24 | 2.87 | 2.72 | 3.31 | 3.05 | 2.60 | 3.28 | 3.04 | 3.20 | 2.99 | 3.09 | 3.71 | 5.01 | 3.31 | 1.801 |
| October .... | 3.733 | 5.05 | 2.62 | 2.97 | 3.45 | 3.40 | 2.39 | 3.92 | 3.46 | 3.40 | 1.80 | 1.54 | 2.18 | 3.01 | 3.07 | 1.977 |
| November .. | 3.710 | 5.84 | 3.83 | 3.65 | 4.00 | 4.17 | 3.29 | 4.69 | 4.18 | 4.20 | 3.29 | 2.54 | 4.87 | 8.07 | 4.31 | 2.038 |
| December .. | 3.431 | 4.17 | 3.50 | 2.62 | 3.64 | 3.50 | 2.30 | 3.33 | 3.10 | 2.80 | 0.42 | 0.40 | 0.35 | 1.60 | 2.51 | 1.564 |
| Total ...... | 35.518 | 49.20 | 30.83 | 29.10 | 34.27 | 32.49 | 27.61 | 36.35 | 34.04 | 35.30 | 26.08 | 22.10 | 33.38 | 48.48 | 33.91 | 19.261 |

ON

# DETECTING THE PRESENCE

OF

# ARSENIC,

## PARTICULARLY IN REFERENCE TO THE EMPLOYMENT OF "MARSH'S TEST."

BY HENRY HOUGH WATSON,

(CORRESPONDING MEMBER OF THE SOCIETY.)

(Received February 2nd—Read February 9th, 1841.)

In cases of poisoning by arsenic, it frequently happens that, after death, adhering to the stomach, or interspersed in the contents of the stomach, are to be found portions of a heavy white powder, in quantity so great that it can be collected and submitted to the process of reduction by carbonaceous matter, as well as part of it exposed to the action of those other chemical operations usually resorted to on such occasions:—in these instances, there is no difficulty in arriving at a positive conclusion, that the white powder operated upon is oxide of arsenic. It is not always,

however, that so much of the powder can be collected separately from the rest of the contents of the stomach as is required for its reduction by carbonaceous matter to the metallic state, or for the distinct exhibition by that agent of the characteristic alliaceous smell of the heated metal; owing to the oxide having been administered in the state of solution, or, if administered in powder, to its having become dissolved by the liquid contained in the stomach, or to its having got intimately diffused and mixed among the other undissolved matter in the stomach. In such instances, without applying a mode of testing published in the year 1836, we cannot so readily conclude as to its presence; but then have to operate upon a fluid by the application of certain tests capable of effecting known chemical changes with arsenious acid, by the power which they possess of acting upon it when in solution. Some of these tests are incapable of giving satisfactory results when the solution of arsenious acid is accompanied by one or more of many ingredients which often form a part of the contents of the stomach; and however strong our suspicions may be, it is not safe to conclude decidedly that arsenic is present when only one of the tests alluded to produces that apparent action which it ought to produce

with a solution of arsenic; the least that is required is, that several of the tests should in the results of their action corroborate each other in the most full and satisfactory manner, unless by the action of one of them alone a precipitate is obtained which can be collected, and which is so free from the objectionable part of the matter from which it has been caused to deposit, that it can be decomposed, and the arsenic contained in it be reduced to, and exhibited in, the metallic state; or, its quantity being sufficient, it be capable of being caused to undergo those changes, whereby such a solution may be formed from it as will completely give all the appearances which are expected from a pure solution of arsenious acid, by the application of those tests which gave unsatisfactory results when applied directly to the fluid contents of the stomach: and it is far from being extravagant to suppose that in cases of poisoning by arsenic it may happen, or that it not seldom does happen, that the alimentary canal of the individual to whom the arsenic was administered, has become evacuated to such a degree before the occurrence of death, that, on *post mortem* examination, the quantity of matter found whereupon to operate, is at most not greater than to allow of the exhibition, to the most skilful

analyst, of a mere trace of the poison sought for.

From these remarks it will be in some degree apparent how much before the year 1836 we were wanting, in regard to our known means of testing for arsenic, a method by which we could not fail in detecting and exhibiting it, when present in very minute quantity, in such complex organic materials as we might have to make the subject of investigation.

In the year mentioned, Mr. James Marsh, of the Royal Arsenal, Woolwich, published a mode of operating which appeared in a great degree to supply what was wanting: and, in viewing his discovery, whether we look upon the principle upon which it is based, or upon the apparatus which he used in carrying it into effect, we cannot but admire its beauty; both the principle and the apparatus being such as for simplicity will not readily be superseded, and the principle one which forbids its actions to be frustrated by the impediments offered by organic substances.*

* The large gold medal of the Society of Arts of London was awarded to Mr. Marsh, for his discovery. His communication is printed in the 51st volume of the Transactions of the Society of Arts, and in the 21st volume of Jameson's Edinburgh New Philosophical Journal.

If diluted sulphuric acid or hydro-chloric acid be allowed to act upon zinc combined with arsenic, or upon zinc in contact with a solution of arsenious acid, or other compound of arsenic, the gas generated is arsenuretted hydrogen—hydrogen holding arsenic in combination. When, therefore, Mr. Marsh has a liquor for examination which is suspected to contain arsenic, and which could not easily be made sufficiently clear, and free from objectionable matter, to admit of being tested by the other usual means, or when he has solid matter, such as pastry, pudding, or the like, which, on being treated with water, gives such a liquor, he mixes the liquor with diluted sulphuric acid, and allows the mixture to act upon pure zinc, whereby hydrogen gas is produced, to which the arsenic is transferred, if any was present in the matter the subject of examination. The gas collected he causes to burn from a jet; and in contact with the flame holds a piece of cold window glass, or the like, on the surface of which a thin film of metallic arsenic immediately deposits when that metal was present in the matter suspected to contain it; or, having set fire to the gas as it issues from the jet, he receives the flame within a glass tube open at the ends, which becomes dimmed by a white powder, if arsenic be present.

With one drop of Fowler's solution of arsenic, which only contains about the one 120th part of a grain, he is able to obtain distinct metallic films. When arsenic is present in large quantity in the matter suspected to contain it, he can separate sufficient in the form of arsenious acid to enable him to form a pure solution from it, the identity of which he can then verify by the several tests usually employed, and which I have before alluded to: but, though his plan of operating is generally applicable, yet it is only indispensable to adopt it, when the poison is present in very minute quantity. Great as is the value at which we are compelled to estimate it in reference to its application where the quantity of poison present is but minute, and entangled with organic matter, there is still reason why it may have been considered incomplete, and viewed as dangerous to have been resorted to by the inexperienced operator, or even by one accustomed to general chemical practice but hasty in arriving at conclusions from mere superficial resemblances.

Had it been the fact that arsenic is the only metal which enters into combination with hydrogen, and which is capable of being deposited upon cold surfaces, when the gas is allowed to undergo

combustion, we might with propriety have concluded that when, on adopting Mr. Marsh's plan, we happened to get a metallic deposit or crust, arsenic was present in the matter under examination; but in the number for May, 1837, of the *London and Edinburgh Philosophical Magazine, and Journal of Science*, Mr. Lewis Thompson directs our attention to a combination of antimony with hydrogen, which he calls antimonuretted hydrogen, and points out the near resemblance which it bears to arsenuretted hydrogen. This combination is procured under circumstances similar to those under which arsenuretted hydrogen is formed; antimony, of course, being substituted for arsenic. The smell of antimonuretted hydrogen in a great degree resembles that of arsenuretted hydrogen; and the two gases are much like each other in their general properties, as I find in corroboration of Mr. Thompson, who says, that when a piece of cold window glass is held in the flame of antimonuretted hydrogen, a metallic crust is deposited, and when a glass tube is used, the metallic film is formed on that part of the tube nearest the flame, and the white oxide around and above it, which appearances coincide in a very remarkable manner with those produced by arsenuretted hydrogen under similar circum-

stances; and although a practised eye may discern some difference between the crusts, that from antimony being more silvery and metallic; yet the line of demarcation is not easily drawn ; for a thin film of antimony looks like arsenic, and a thick crust of arsenic has the metallic appearance of antimony : and, after showing the similarity of appearances produced by sulphuretted hydrogen upon the oxides of the two metals, and the fallacious results likely to be arrived at in endeavouring to determine which of the two is present by the ammoniacal sulphate of copper, he states that they may be distinguished by adding a drop of nitric acid to the crusts, which will dissolve them, and on evaporation to dryness a white powder be left in each instance : a little of a dilute solution of nitrate of silver being added, and the whole then exposed to the fumes arising from a stopper moistened with ammonia, the antimonial solution will deposit a dense white precipitate, whereas that from arsenic will give the well known canary yellow flocculi : he prefers this mode of using silver to the ammoniacal nitrate of that metal, because the slightest excess of ammonia destroys the colour, but by watching the effect of the vapour, the exact quantity requisite is easily

obtained. This plan, which Mr. Thompson suggests of determining of which of the two metals a crust consists, is ingenious, and should be adopted in all suitable instances; but from experiments which I have made, I am forced to conclude that it does not always prove satisfactory—that by it indubitable results can only be obtained when the crust is very thick, or when its surface is extensive, or, in other words, when the quantity of metal deposited is considerable. When the crust operated upon is arsenic, and only a thin one, or sparing in quantity, the colour of the flocculent precipitate cannot so distinctly be perceived to be yellow as to warrant us in coming to that decision, neither can its flocculent appearance be distinctly perceived, and we cannot certify that the metal in question is not antimony; the plan, therefore, is in a great measure liable to the same kind of objections which are to be urged against the sulphuretted hydrogen, and the sulphate of copper tests; and I may add, that in this alleged instance of only a slight crust, there seems reason to doubt whether the result of the silver test alone applied as described should be allowed more forcibly to govern our decision, than the distinction to be perceived between the appearances of the

crusts of the two metals under some circumstances, and particularly when they are examined by a practised eye. Indeed, Mr. Thompson concludes his communication by stating, that he fears we can only regard Mr. Marsh's very ingenious test as furnishing good collateral evidence, capable, in scientific hands, of giving very correct indications, but wholly unfit to be entrusted to those unaccustomed to careful chemical manipulation: he says this with a thorough conviction of the great utility of the test, and is only sorry that its evidence is not unequivocal.

This announcement of Mr. Thompson was the cause of a subsequent paper by Mr. Marsh, appearing in the Phil. Magazine for Oct., 1839, in which he said he was happy in being able to lay before the readers of that journal, a very simple distinguishing test for arsenic and antimony; and stated it to be as follows:

After the common arrangements have been made for testing for the metals in question, the piece of glass or porcelain, on which the metallic crusts are generally received, is to have a drop of distilled water placed on it; it is then to be inverted, so that the drop of water is suspended

undermost. The gas as it issues from the jet is to be inflamed in the usual manner, but the piece of glass with its drop of water is to be held about an inch above the jet, or just above the apex of the cone of flame: the arsenic by this arrangement is oxidised at the same time that hydrogen is undergoing combustion, and coming in contact with the drop of water held above, forms a solution of arsenious acid, should arsenic have been in the mixture submitted to examination: a minute drop of ammoniacal nitrate of silver being dropped on the solution so obtained, if arsenic be present, the well known characteristic lemon yellow colour produced by this test, when used for testing for that substance, is immediately produced, viz., the insoluble arsenite of silver; antimony under the same circumstances produces no change. He hopes that the process will be found to possess all the delicacy and precision necessary for distinguishing the two metals from each other, and that it will be the means of removing every doubt from the minds of experimentalists in future. I should have been glad to have been able to say Mr. Marsh's hopes are realized; it happens on the contrary, however, that I must give my decided opinion, that the results obtained by his mode of testing ought not to be considered

indubitable, since it is a well known fact that *phosphoric acid* gives with ammoniacal nitrate of silver, a yellow precipitate not easily distinguishable when in small quantity from that produced by arsenious acid ; and, I find that by putting into Mr. Marsh's apparatus a little of a solution of antimony, and a little phosphuret of lime (or other substance capable of yielding phosphuretted hydrogen) along with the usual pure sulphuric acid and pure zinc, and without arsenic in any form, gas is produced, from the flame of which a metallic film, or crust, may be obtained; and which gas, by being allowed to burn under a drop of water, as recommended by Mr. Marsh, gives the water the property of depositing a yellow precipitate when the ammoniacal nitrate of silver is added; and, in addition to this, the gas possesses a smell resembling, in a high degree, that of arsenuretted hydrogen.

Reflecting upon the characteristic distinctions which exist between arsenic and antimony, and participating in the anxiety to remove any embarrassments prevailing against the perfection of a method of operating which presents such conveniences as Mr. Marsh's original discovery does, I have been induced to conceive that the effect

of the application of heat might with success be had recourse to in enabling us more positively to conclude of which of the two metals any crust or deposit we may have obtained is formed: and during the months of November and December last, I made repeated experiments, which, I think, proved the accuracy of the notion I entertained. Considering the readiness with which metallic arsenic volatilizes, and that it is said to be fusible at or below 400° of Fahr., while antimony requires about 800° for fusion, I thought it probable that there might be a wide thermometric range between the points at which the two metals were volatile or evaporable, and I commenced experimenting as follows. Having procured a number of slips of window glass, each about the 1-10th or the 1-8th of an inch wide, and several inches long, I, by the aid of Marsh's apparatus, caused metallic films, or crusts, of arsenic, to be deposited upon some of them, and of antimony upon others. I then provided a number of thin glass tubes, sealed at one end, and only about wide enough to admit the slips of window glass into them. Into one tube I put a slip of the window glass, coated *thickly* with arsenic, and into another a slip coated *very thinly* with antimony— in each case the slip being shorter than the tube,

and then hermetically sealed, with a blow-pipe flame, the orifice of the tubes. Thus arranged, the tubes enclosing the slips were immersed to a little more than the depth of the coated part of the slips, ($2\frac{1}{2}$ inches, the length of the tubes being about five inches,) in a bulb containing rape oil in a state of ebullition. In one minute the arsenic had entirely disappeared from that part of the slip surrounded by the hot oil; but the antimony did not entirely disappear before the expiration of seven minutes. Other subsequent experiments of the same kind, corroborated the conclusion arrived at in this instance, that a very thin film of antimony was very much longer in evaporating away, by the heat given by boiling oil than a very thick crust of arsenic. The next object was to endeavour to find a temperature lower than that of boiling oil, at which arsenic would entirely volatilize, and antimony remain permanently fixed; and about the beginning of November I made numerous experiments, similar to the above, but taking care that the oil from which the heat was communicated was kept at a temperature ranging from 490° to 500°, a thermometer being all the time kept immersed in it. In some instances thick crusts of arsenic were entirely volatilized in about fourteen minutes,

and, in other instances, crusts less thick disappeared in about eight minutes ; the length of time required for the entire volatilization depending upon the thickness of the crust; but *very thin* films of antimony stood the temperature for an hour, without volatilization taking place in any perceptible degree. I next conducted similar experiments at a temperature ranging only from 355° to 365°, and found *very thick* crusts of arsenic to be volatilized in three or four hours, thin ones disappearing in half an hour or less ; those formed from gas produced by acting upon zinc with 400 gr. mea. of diluted sulphuric acid, (one volume concentrated acid to seven water) containing one drop of a solution of arsenious acid, sp. gr. 1.026, disappeared in half an hour, while those of antimony, apparently of the same density, did not diminish in the slightest perceptible degree in twenty hours; and it did not seem probable that they would have diminished, however long they had been submitted to the same temperature, that being lower than the point at which antimony begins to volatilize.*

* From the eleventh edition of Dr. Henry's Elements of Chemistry, Vol. II, page 81, it is to be found that Thenard asserts that antimony is not volatile, when exposed to heat in closed vessels, if atmospheric air be carefully excluded, and no

About the time I was making these experiments, I communicated my ideas to my friend, Dr. Haworth, of this town (Bolton); and, in several weeks afterwards, he informed me that a number of the *Lancet*, just published, stated that M. Orfila had been describing in France different processes which might be adopted in distinguishing of which of the two metals a crust consisted, and amongst them he mentioned the application of heat; I, however, did not get to see the *Lancet*, nor did I learn the particulars of what was said regarding the application of heat, but about the beginning of this month my friend kindly put into my hands the *British and Foreign Medical*

gaseous matter be generated during the process. This, if true, would have been exceedingly favourable to my mode of distinguishing between arsenic and antimony; but the assertion is not to be relied upon. I took a narrow tube, sealed at one end, nearly filled it with cold silex in very fine powder, which had only a few minutes before been exposed to a red heat, and then pushed into it, through the powder, a slip of glass, having crusts of antimony upon it. By this management the metal was secluded from air of every kind, and confined in a medium for which it possessed no chemical affinity. Thus prepared, the tube was immersed to about half its depth in boiling oil, and the antimony volatilized, and left that part of the slip surrounded by the hot oil in as short a time as if atmospheric air had been present.

I submitted a slip having arsenic upon it, to a similar experiment, and obtained a corresponding result.

*Review*, for Jan., 1841, which contains a review of M. Orfila's *Memoirs on Poisoning*, printed in the Memoirs of the Royal Academy of Medicine, Vol. VIII., *Paris*, 1840; by this I find that the agency of heat spoken of by Orfila, is through the direct application of *flame* to the metal under examination. He says, that an arsenical stain, of whatever thickness, is entirely volatilized in from half a minute to a minute, when exposed to the flame of hydrogen gas, as in the common philosophical lamp; the antimonial stain, on the contrary, even when thin, is not volatilized until after the lapse of five or six minutes. This application of heat by flame is so indefinite in degree, and so wanting of that precision without which we greatly risk the danger of deciding erroneously, that I hesitate not at announcing my mode of applying heat, as one in which we may with more safety confide.

It will be observed, that I enclose and hermetically confine the metallic crusts in a tube, so that no portion can escape, although a volatile tendency be given them by the heat, which is an advantage not possessed when flame is directly applied to them unconfined, the metal then being dissipated and lost. When the temperature has

caused the crust, if of arsenic, to be volatilized from that part of the slip of glass on which it was deposited, small crystals are to be observed adhering to that part of the slip and of the interior of the tube, which was not immersed in the hot oil, chiefly to that part which was from $\frac{1}{4}$ to $\frac{1}{2}$ an inch above the surface of the oil. It will be perceived, too, that I do not lose the chance of trying the action of the other usual tests, but that I have an opportunity of testing in a two-fold manner the character of any crust in question: having cut off with a file one end of the tube, the metal or its oxide can be operated upon with nitric acid and the ammoniacal nitrate of silver, or with such other tests as we may choose to apply.

The greatest objection against my mode of operating is the tediousness attending the having to wait so long for the conclusion of an experiment, and the great care required in watching the range of the thermometer; but, I hope, this may be alleviated by substituting for oil as the heating medium, some other liquid whose boiling point is stable within the range of the temperature required: probably a *saturated* solution of some salt may answer, but, at present, I am not aware of any that will.

Mr. Marsh's original discovery, *per se*, is invaluable in enabling us with ease and certainty to bring out from among organic materials arsenic, when present in very minute quantity, and in giving us the power of submitting it to ocular demonstration; but it is wanting in the capability of convincing us that what we separate, from suspected matter, having the superficial appearance of arsenic, is most decidedly in every instance that metal; it leaves us to find out by other means whether the metallic looking substance is arsenic, or antimony, or something else. Though there may be other substances besides arsenic and antimony capable of combining with hydrogen, and of giving the flame of that gas the property of depositing upon cold surfaces dark coloured films or crusts having more or less of a metallic lustre, yet, I think it is not probable that any substance besides antimony will cause a film or crust, so nearly resembling one of arsenic in appearance and chemical properties, as to settle strong doubt upon the mind of an experimentalist accustomed to investigations, such as the one under consideration. Orfila states, that he has observed stains to result even from organic matter only; but these differed from arsenic in being less volatile, and in having none of the chemical

less volatile, and in having none of the chemical characters of that metal. Then, since the question is only likely to be whether or not a given metallic deposit is arsenic or antimony, I trust that my mode of applying heat, particularly in addition to the method of testing recommended by Mr. Thompson, will tend to make Mr. Marsh's discovery as perfect as it probably ever will be; and, I doubt not, that "Marsh's test" will continue to be regarded as a valuable assistant in a chemical laboratory. I have myself often applied it successfully in determining the presence of arsenic, in small quantity, in minerals I have had under examination; in such instances, I venture to suppose no one will dispute its utility; but, in cases of poisoning, unless a large quantity of the suspected arsenical ingredient can, by direct means, be produced, it ought not to be regarded in a stronger light than capable of furnishing good collateral evidence; it must, indeed, be lamentable to consider that so much confidence should be placed upon appearances produced by its operation, as to cause a positive conclusion to be arrived at that death was caused by arsenic, when it had been needful to resort to intricate manipulation in order to detect the requisite characteristics, and when, at length, only a slight crust or film could be obtained. In cases of poisoning, no man,

however high his reputation as a chemical analyst, or as a toxicologist, has a right to be satisfied that any metallic looking substance is arsenic, which, by the apparatus in question, he may have separated from matter suspected to contain it, unless the quantity is so great that he can verify his suspicions, not only by ascertaining the temperature at which it is volatile, but by the application of other indubitable tests.

Before concluding, I must not neglect to mention the great necessity which exists, in the application of "Marsh's Test," previously to examine with the utmost care the purity of the articles to be used. It is requisite to see that the apparatus is entirely free from arsenic; and that not only the zinc is pure, but particularly the *sulphuric acid;* for, at present, the sulphuric acid of commerce, as ordinarily produced from pyrites, is *strongly impregnated with arsenious acid.** And from facts which have come under my observation, I may add that hydro-chloric acid (muriatic acid) produced through the agency of such sulphuric acid is also impregnated with arsenic. I have not yet

* Since this paper was read, I have found 1000 grains, by weight, of a commercial sample of concentrated sulphuric acid, to contain $5\frac{1}{2}$ grains of arsenious acid.

seen any nitric acid produced through the agency of the impure sulphuric; but, probably, in such, arsenic would likewise be found.

Before using any one of the three acids, we cannot be too careful in minutely examining its purity.

In Mr. Marsh's communication to the Society of Arts, he suggests determining the purity of the zinc by putting a bit of it into the apparatus, with some diluted sulphuric acid only; and if the gas obtained on being set fire to, as it issues from the jet, will deposit no metallic film on a bit of flat glass submitted to the flame, and yield no white sublimate within an open tube; the zinc may be regarded as in a fit state for use. The purity of the zinc being known, the like process might, of course, be resorted to in determining the fitness of the sulphuric acid for use; but, I will remark as a caution, that in determining the freedom of either the zinc, or the acid, or the apparatus from arsenic, it is much preferable to hold a cold substance of *large bulk* to the flame, from a small jet, instead of a *bit* of glass, for I have found that when the gas contains only an exceedingly minute quantity of arsenic, a distinct metallic deposit

cannot be obtained upon a small bit, or thin piece, of glass, and the result of the experiment is such as would lead one to suppose that the materials are fit to be used in an investigation of poisoning; but when a cold solid substance of the bulk of several cubic inches, as, for instance, the thick end of a Wedgwood's ware pestle, is held to the flame, a dense metallic crust may be obtained: the reason of this is easily explained,—the heat communicated to a small bit, or thin piece, of glass, by the combustion of the hydrogen, soon becomes so great as to keep the arsenic in a volatile state; but a large solid substance is a long time in becoming hot, and, consequently, upon it the metal continuously, though slowly, and by little and little, deposits, until ultimately a very distinct and even dense crust is obtained. It is obvious, that if this precaution of holding a large cold substance to the flame be not attended to in testing the purity of the materials, and if then, by the application of such large substance to the flame of gas produced after the introduction, into the apparatus, of any matter suspected to contain arsenic, a deposit of that metal be obtained, a very great risk is run of forming an erroneous and dangerous decision.

In consequence of the sulphuric acid of com-

merce containing arsenic, it cannot but be expected that many of the ingredients or compounds into which that acid enters as a constituent, as well as some of those of which it is not a constituent, but in the formation of which it has been employed as an agent, will be liable to be more or less contaminated with arsenic. I have detected arsenic in the sulphate of potash (commonly known in chemical manufactories under the name of "*sal enixum*"), though in the formation of this salt a considerably high temperature had been employed, which many persons probably might suppose would have had the effect of expelling all the arsenic. There is reason to expect its presence in alum, not only since such sulphate of potash as I have mentioned is used in alum making, but also as sulphuric acid is directly applied in the formation of the sulphate of alumina used.* And, the probability arises, that food may in some instances be contaminated with it; alum being an article which bakers often use in admixture with the other usual constituents in the mak-

* Since writing the above, I have obtained a commercial sample of alum, which had been produced by the aid of pyrites sulphuric acid, and found it to be accompanied by a trace of arsenic.

ing of bread.* Hence, in investigating whether or not, in any instance, poison has been intentionally and maliciously administered; it is indispensable, when, on testing, we certainly detect the presence of arsenic, to ascertain completely that what we detect has not had its introduction from some accidental source; no less is it the duty of a court of judicature to receive with the most scrutinous examination all evidence tendered on the subject, particularly when the quantity of arsenic detected is but small; and, from the facts and probabilities to be gathered from what I have adduced in this paper, together with the circumstance of the great lack of chemical science among the generality of the members of the bar, I feel that I may, without hesitation, express my strong belief, that a person standing accused of having wilfully caused the death of another by poison, is far from being sure to have that fair treatment which he has a right to expect from a court whose only object is to deal out impartial justice,

* It is very likely, that vinegar may hereafter (when pyrites acid has got into more general use than at present) be found to contain arsenic; the manufacturers of vinegar being in the habit of adulterating it with sulphuric acid, which the law allows them to do to a limited extent.

if the counsel employed for his defence be not assisted by the evidence, or instruction, of some one skilled in the principles and practice of chemistry.

Bolton-le-Moors,
*Jan. 25th*, 1841.

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## APPENDIX TO THE FOREGOING PAPER.

In the London and Edinburgh Philosophical Magazine, published yesterday, I find a communication from Mr. Marsh, "*On testing for Arsenic and Antimony, by Hume's Process*," in which he submits to the readers of that journal, a modification of the mode of applying Hume's test (the ammoniacal nitrate of silver) which he described in the said journal, published October, 1839. Instead of the drop of water, suspended to the inverted glass, being held over the flame of gas, and the ammoniacal nitrate of silver being afterwards applied, he, at once, having moistened one side of a piece of glass with the test solution, holds it, with the moistened side downwards, over the flame, when, if arsenic be present, the characteristic yellow precipitate is produced, and, if

antimony be present, a white precipitate is obtained, while, if neither arsenic nor antimony be present, the silver of the test liquor is reduced to the metallic state.

In this modification of the application of Hume's test, there is nothing whereby any of the doubt can be removed, as to whether a yellow precipitate produced is the consequence of the action of arsenious acid, or of phosphoric acid upon the test. *See pages* 600 *and* 601, *of this volume.*

H. H. WATSON.

*June 2nd*, 1841.

# OBSERVATIONS

ON THE

VARIOUS ACCOUNTS

OF THE

# LUMINOUS ARCH, OR METEOR,

ACCOMPANYING THE

# AURORA BOREALIS

OF NOVEMBER 3rd, 1834.

BY JOHN DALTON, D.C.L., F.R.S.S. L. & E.
MEMBER OF THE INSTITUTE OF FRANCE, &c., &c.

(Read 26th December, 1834.)

On the 3rd of November, 1834, in the evening, I observed a horizontal light very conspicuous in the magnetic north; but could not distinguish *Streamers*, it continued without much change for two or three hours. It was afterwards stated to me that *Streamers* had been seen in the early part of the evening.

A little before eight o'clock (true mean time) I was informed by two of my pupils that a fine

arch to the south was observable; on looking I beheld a beautiful and brilliant well defined arch crossing the magnetic meridian at right angles; its summit was 10°+ to the south of the zenith, about 4 or 5 degrees broad, and extending from about 20 degrees altitude east to 20 degrees west. It continued, without any sensible variation in position, for about one quarter of an hour after I saw it, and it had been seen for a considerable time before eight. The star Almach (foot of Andromeda) was near the magnetic meridian, and the arch was as far above it as the breadth of the arch by estimation. The arch soon advanced to the south about 20 degrees and became fainter, but continued visible till half or three quarters past eight o'clock, when it entirely vanished. About half-past eight a bright *falling star* shot from the south-east along the line of the arch from east towards the west about 30 degrees of altitude—its course was from 5 to 10 degrees in extent. The Aurora in the north continued long after.

The appearance of an auroral arch, such as was presented on the evening of the 3rd of November last, is a rare phenomenon. I do not remember to have seen more than one before,

and that was nearly forty-two years since; it is described at length in my Meteorological Observations, published soon afterwards. There was another very fine Aurora seen in 1826, of which I wrote an account published in the Philosophical Transactions of the Royal Society the same year. This was extensively seen, and variously described by observers, from Edinburgh to Warrington. It ought to have been seen at Manchester, but probably the cloudy atmosphere prevented; some streamers however were seen here about the time when the arch disappeared at other places.

I believe no modern meteorologist has expressed a doubt that this arch-like appearance in the sky is only a modification of the more common appearance of the Aurora Borealis. In fact, the common streamers generally, if not always, accompany the arch, but mostly at a great distance from it in the heavens, and as if the accompaniment was accidental.

Every one who will take the trouble of stripping the auroral phenomena of their optical illusions, must be aware that the *common streamers* are beams of light almost vertical, or perpendicu-

lar to the horizon; but in reality inclining to the south in their ascent, from 10 to 20 degrees; those in the magnetic north (from the optical deception) appear absolutely perpendicular to the horizon, but those near the east and west of the magnetic meridian show their true position, namely that of the dipping needle. The east and west *arches*, on the other hand, (such as the one on the 3rd ult.) are beams of light stretching over the earth horizontally from east to west, every-where of the same height above the earth's surface whatever that height may be.

I have for the last forty years considered both arches and beams to be constituted of *magnetic* matter, and in ordinary circumstances invisible; but when a disturbance of the electric fluid takes place in the upper regions, these beams, &c. serve to convey the electric fluid from one place to another to restore the equilibrium, which occasions the luminous appearances.

The following accounts of this arch as noticed by different observers have been sent to me.

"Mr. Paul Moon James, of Birmingham, favoured me with an account of this Aurora as seen at Moseley, near that town. Its appearance as described by him was very similar

to its appearance in Manchester—so much so, that the account in one place would do for the other. A beautiful luminous arch of red and white light stretched across the sky from nearly east to nearly west—its highest point a few degrees south of the zenith. It varied occasionally in colour and intensity and faded away gradually, lasting from about a quarter before to nearly half after eight."

## Mr. William Hadfield's account of the Aurora Borealis, as seen by him on the 3rd. of November, 1834, at Cornbrook, near Manchester, Latitude, 53° 28′ 4″ North. Longitude, 2° 14′ 0″ West.

"At 7h. 45m. P.M., a luminous arch was visible nearly at right angles with the north pole. The eastern end appeared to rest on Jupiter, which was then about 21 degrees above the horizon, the sky being cloudy below; but the arch was visible through small openings between the clouds. The eastern end of the arch appeared to terminate in the horizon, about 8 degrees north of east; from Jupiter upwards, it passed about 4 degrees north of the Pleiades, about 2 degrees south of Algol, in Caput Medusæ, about 4 degrees north of Almach, in Andromeda, and about 4 degrees south of Shedir, in Cassiopeia; its greatest altitude being about 2 degrees south of the zenith, passing over Aided, in Cygnus, and Gamma, in Lyra, proceeding to the western horizon, about 4½ degrees south of Ras Alhagus, in Serpentarius, and terminating about 10 degrees south of west. From 7h. 45m. to 8h. 15m. P.M., the arch was gradually moving to the south. At the latter time it began to be stationary, more

diffuse and fainter than at first. The eastern end of the arch passing about 2 degrees south of Aldebaran, terminating at the horizon, about 10 degrees north of east. From Aldebaran upwards, it passed about 7 degrees south of the Pleiades, over Beta, in Aries, about 5 degrees north of Algenib, in Pegasus. The highest point, or middle of the arch, was about 31 degrees south of the zenith, and passing to the west, about 3 degrees north of Epsilon, in Pegasus's mouth, and about 4 degrees south of Altair, in Aquila, resting in the western horizon, about 14 degrees south of west. The arch at half past eight o'clock, became very faint and very diffuse, —at nine o'clock, the sky was covered with clouds, which prevented further observation."

## An account of the Aurora Borealis, observed by Peter Clare, the 3rd of November, 1834, at Oulton Park, in Cheshire, the seat of Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S. Latitude, 53° 12′ North. Longitude, 2° 30′ West.

"The clouds which had caused the evening to be very dark, began to disperse about seven o'clock P. M., and at twenty-five minutes after seven, a light was observed prevailing over the northern part of the hemisphere, being most luminous at two places about 15° above the horizon, one a little to the east of north, and the other nearly west: immediately afterwards, many bright streamers darted upwards from the northern horizon, whilst others still brighter, commenced in the light portion of sky at various heights up to 40°, all pointing towards the magnetic zenith; a great portion

of them extending to the milky way, and some even beyond it: there were also several broad flashes of light, which rose rapidly from the north towards the zenith. These appearances continued about five minutes, during which time the light was so brilliant that the time by a watch could easily be distinguished. At half-past seven the streamers disappeared, the light began to wane, and gradually diminished until nine o'clock, when it was scarcely visible.

"At ten minutes after eight o'clock, the same evening, the sky having become quite clear a bright zone of light was observed from east to west, the upper edge being sixty degrees above the horizon at the highest part, and the lower edge fifty-two degrees, and consequently was eight degrees broad; but towards the east and west horizon its breadth was from six to seven degrees; it appeared more brilliant in the west than in the east, particularly near the constellations Delphinus and Aquila, where it was the brightest. The zone or arch proceeded from a little to the north of east, in the upper part of the constellation Orion, and passed through Taurus, Aries, the upper Fish, Pegasus, Equuleus, lower part of Delphinus, head of Aquila, upper part of Antinous, and terminated to the south of west in Sobieski's shield. In five minutes afterwards the upper part of the arch had descended about two degrees, and the east end became less brilliant and in ten minutes more, both ends, viz. below the Pleiades in the east, and head of Aquila in the west appeared to be bent upwards. In a short time the light began to wane rapidly, and at thirty-five minutes after eight the arch had disappeared."

## Aurora Borealis observed at Bolton-le-Moors, by Mr. H. H. Watson.

"At twenty minutes past seven on the night of the third of November, 1834, I observed at Bolton-le-Moors a little light in the north, which rapidly grew larger: at twenty-five minutes past seven, two arches appeared in it, and also a few streamers, some of which were very bright. This light in the north soon grew duller, but extended more to the east. At eight minutes before eight, a very bright well defined arch, apparently about twice the breadth of an ordinary rainbow, and a little *south* of the zenith, instantly shot from west to east, and remained till half-past eight: about ten to fifteen minutes past eight, it increased to double its original width, but at the same time began gradually to decline in brilliancy, and continued to do so till it quite disappeared at half-past eight: one end of it reached a little more towards the eastern horizon than Sirius; at first it was rather more north than Pleiades, but at last rather more south: what stars its apex approached I do not know, neither do I know what stars its western end approached; I think, however, that it extended as near due west as possible.

"By half-past eight the Aurora had extended into the west, but was throughout very much obscured by clouds. At a quarter-past nine, clouds had so spread themselves, west and east, that no light was to be seen, except a little in the north. At ten the light was entirely gone."

## From the *Literary Gazette*, November 15th, 1834. (See page 769.)

"On Monday and Tuesday (3rd and 4th instant) the sky presented a most beautiful appearance, the corruscations of the aurora were so brilliant as to afford a very sensible light. The heavens, on the first evening between eight and nine

o'clock, were covered (more especially northward) with fleecy clouds, shining with a mild lustre; from the westward, and reaching to the zenith, was a broad stream of light in constant motion. A white bow, the most beautiful I ever beheld, nearly the breadth of the moon, tapering at the eastern extremity, and in appearance like the galaxy, reached quite across the heavens from east to west through the zenith, evidently crossing the magnetic meridian, the stars which shone through it were surrounded with a halo. I could compare it only to an immense white rainbow."

"Wells, Norfolk."

In the 36th, 41st, 46th, 71st, 80th, and other volumes of the Philosophical Transactions, are recorded observations and accounts of auroral arches which had been seen at different places and at various times, both in this country and on the continent.

In the 80th volume there is an account by Mr. Hey of Leeds, of several luminous arches which he observed:—one he saw at Buxton in March 1774, about 8 o'clock p. m.; its appearance and position were very similar to that seen the 3rd of November 1834.

In October 1775 he saw a similar arch at Leeds, but it disappeared in five or six minutes after he first noticed it.

Between eight and nine o'clock p. m., March 21, 1783, he observed a luminous arch, which was visible for ten or twelve minutes; and after it disappeared, another arch, more beautiful, made its appearance and continued visible for half an hour.

On the 26th of the same month, he saw another luminous arch, which remained visible about half an hour.

On the 12th of April, between nine and ten o'clock p. m. there appeared the grandest specimen of this phenomenon which he had witnessed; and on the 26th of the same month he observed three luminous arches.

After comparing his observations with each other, and with those made in London by Mr. Cavallo; at Oxford, by Mr. Swinton; Plymouth, by Dr. Huxham; and Wells in Norfolk, by Mr. Sparshal, Mr. Hey was of opinion that these arches were of the same nature as the aurora borealis.

In the same volume of the Philosophical Transactions there are accounts by the Rev. F. J. H. Wollaston, of Cambridge; the Rev. B. Hutchinson, of Kimbolton; J. Franklin, Esq., of Blockley; and Edward Pigott, Esq., of Kensington; of a luminous arch observed by them on the 23rd of February, 1784, about nine o'clock p. m.; and also some remarks written by the Hon. Henry Cavendish, on the height of this arch, which he calculated from the appearances at Cambridge and Kimbolton; the latter being about seven geographical miles north of the former place. He concludes that the arch could hardly be less than fifty-two miles, and not likely to have exceeded seventy-one miles from the earth.

The distance of Moseley, near Birmingham, being about sixty miles south of Manchester and nearly in the direction of the magnetic meridian,

affords more ample scope for a base line than the distance between Cambridge and Kimbolton, and therefore I think the luminous arch of November 3rd, 1834, was probably six hundred or eight hundred miles from the earth; being far beyond the height as calculated by Mr. Cavendish, of that which was seen at Cambridge, Kimbolton, &c.

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| Charles Heard Wild | January 25th, 1842 |
| Matthew A. Eason Wilkinson, M.D. | January 26th, 1841 |
| William James Wilson | April 29th, 1814 |
| Thomas Woodcock Winstanley | January 26th, 1841 |
| Gilbert Winter | November 2d, 1810 |
| Geo. Wm. Wood, M.P., F.L.S., &G.S. | April 24th, 1807 |
| William Rayner Wood | January 22d, 1836 |
| Bennett Woodcroft | January 26th, 1841 |
| Edward Woods | April 30th, 1839 |
| Robert Worthington | April 28th, 1840 |
| | |
| Joseph St. John Yates | January 26th, 1841 |